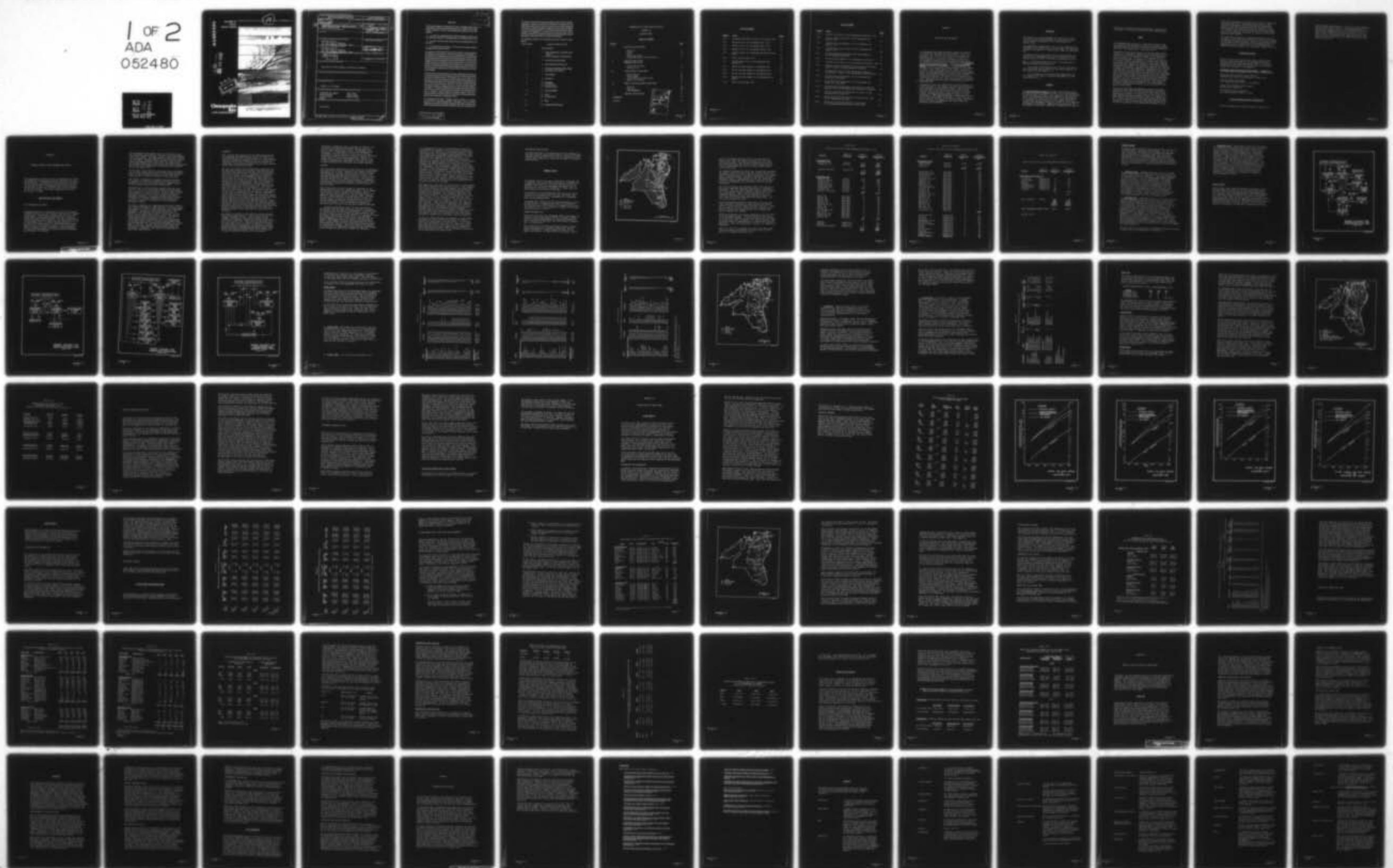
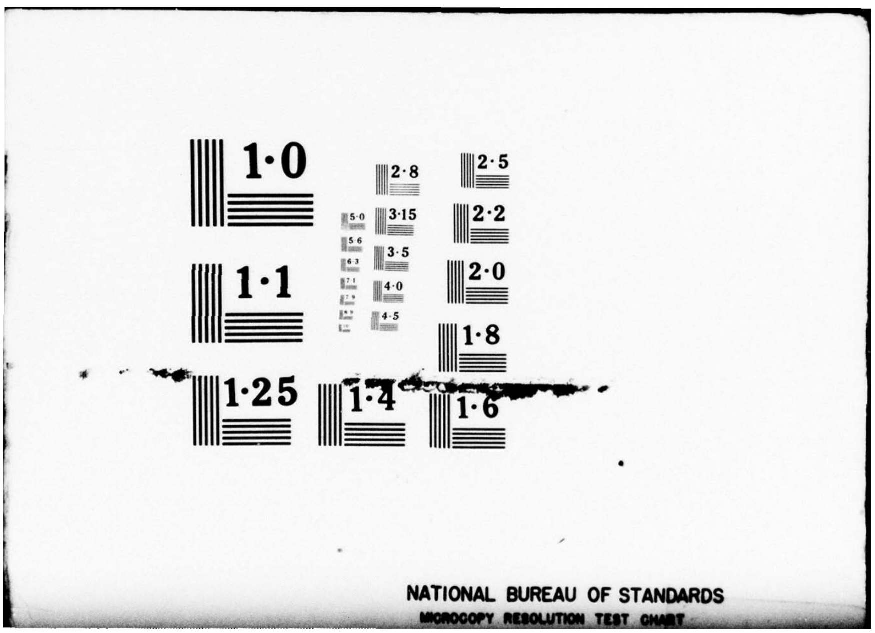
AD-A052 480 CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT F/G 6/6
CHESAPEAKE BAY FUTURE CONDITIONS REPORT. VOLUME 10. POWER, NOXI--ETC(U)
DEC 77

UNCLASSIFIED FCR-77-010 NL

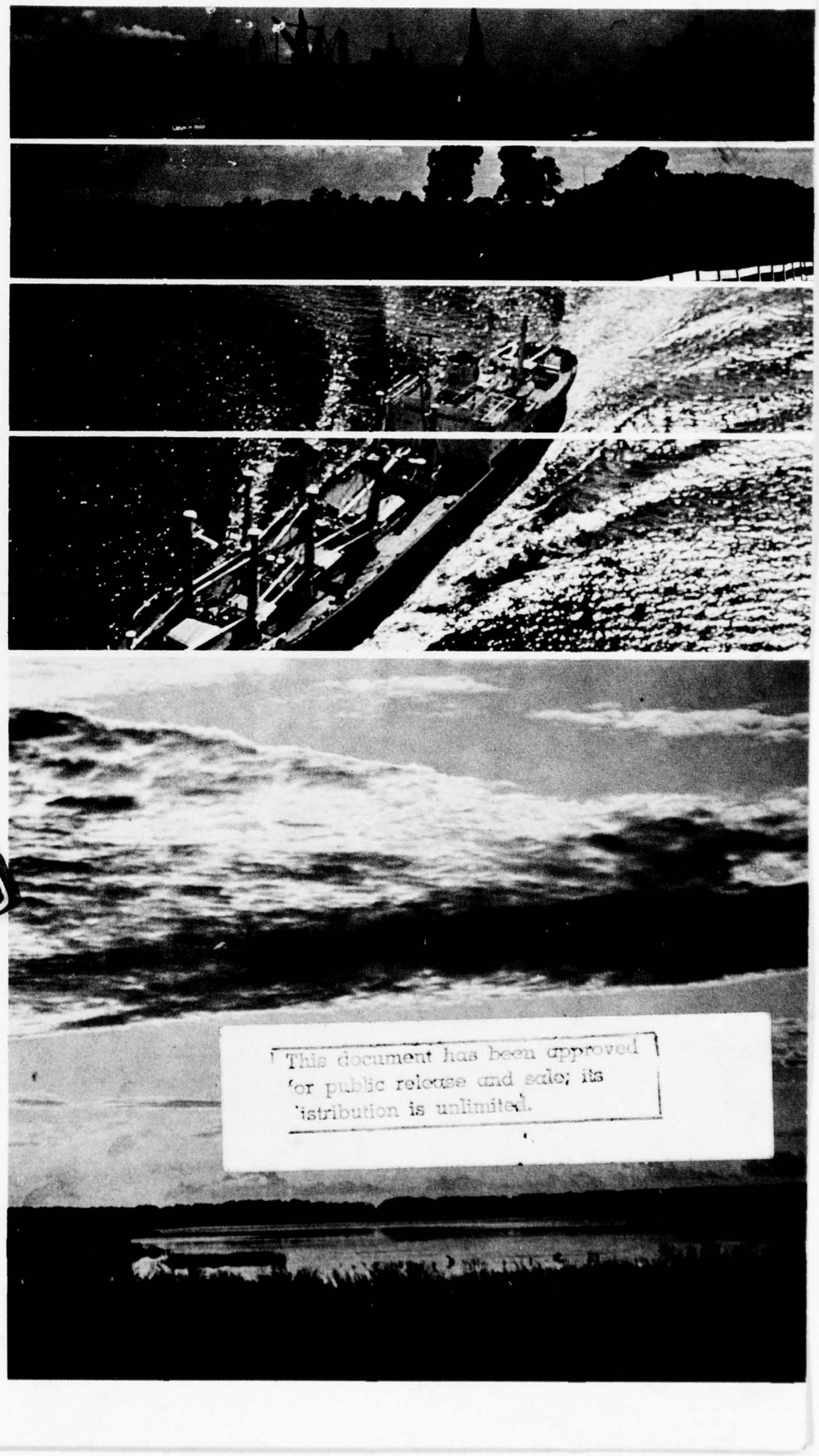
1 OF 2
ADA
052480




1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5
5·0
5·6
6·3
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

14

VOLUME 10
Power,
Noxious Weeds



Chesapeake Bay
FUTURE CONDITIONS REPORT

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 14 FCR-77-Ø1Ø	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 Chesapeake Bay Future Conditions Report. Volume 1Ø. Power, Noxious Weeds.		5. TYPE OF REPORT & PERIOD COVERED INTERIM Rept. 6. PERFORMING ORG. REPORT NUMBER 9
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Baltimore District U.S. Army Corps of Engineers Box 1715, Baltimore, Maryland 21203		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Baltimore District U.S. Army Corps of Engineers Box 1715, Baltimore, Maryland 21203		12. REPORT DATE 11 Dec[redacted]77 13. NUMBER OF PAGES 161
14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*) 12 165p.		15. SECURITY CLASS. (*of this report*) 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for Public Release, distribution unlimited

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

Volume X of 12 Volumes

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Chesapeake Bay Region
Water Resources
Electric Power
Energy
Power Plant
Noxious Weeds
Aquatic Plants

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

See Preface

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE 4Ø9 111

SECURITY CLASSIFICATION OF THIS PAGE (*When Da*

PREFACE

The Corps of Engineers' comprehensive study of Chesapeake Bay is being accomplished in three distinct developmental stages or phases. Each of these phases is responsive to one of the following stated objectives of the study program.

1. To assess the existing physical, chemical, biological, economic and environmental conditions of Chesapeake Bay and its related land resources.

2. To project the future water resources needs of Chesapeake Bay to the year 2020.

3. To formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

In response to the first objective of the study, the initial or inventory phase of the program was completed in 1973 and the findings were published in a document titled *Chesapeake Bay Existing Conditions Report*. Included in this seven-volume report is a description of the existing physical, economic, social, biological and environmental conditions of Chesapeake Bay. This was the first published report that presented a comprehensive survey of the entire Bay Region and treated the Chesapeake Bay as a single entity. Most importantly, the report contains the historical records and basic data required to project the future demands on the Bay and to assess the ability of the resource to meet those demands.

In response to the second objective of the study, the findings of the second or future projections phase of the program are provided in this the *Chesapeake Bay Future Conditions Report*. The primary focus of this report is the projection of water resources needs to the year 2020 and the identification of the problems and conflicts which would result from the unrestrained growth and use of the Bay's resources. This report, therefore, provides the basic information necessary to proceed into the next or plan formulation phase of the program. It should be emphasized that, by design, this report addresses only the water resources related needs and problems. No attempt has been made to identify or analyze solutions to specific problems. Solutions to priority problems will be evaluated in the third phase of the program and the findings will be published in subsequent reports.

The *Chesapeake Bay Future Conditions Report* consists of a summary document and 16 supporting appendices. Appendices 1 and 2 are general background documents containing information describing the history and conduct of the study and the manner in which the study was coordinated with

the various Federal and State agencies, scientific institutions and the public. Appendices 3 through 15 each contain information on specific water and related land resource uses to include an inventory of the present status and expected future needs and problems. Appendix 16 focuses on the formulation of the initial testing program for the Chesapeake Bay Hydraulic Model. Included in this appendix is a description of the hydraulic model, a list of problems considered for inclusion in the initial testing program and a detailed description of the selected first year model studies program.

The published volumes of the *Chesapeake Bay Future Conditions Report* include:

Volume Number	*Appendix Number and Title*
1	Summary Report
2	1 — Study Organization, Coordination and History 2 — Public Participation and Information
3	3 — Economic and Social Profile
4	4 — Water-Related Land Resources
5	5 — Municipal and Industrial Water Supply 6 — Agricultural Water Supply
6	7 — Water Quality
7	8 — Recreation
8	9 — Navigation 10 — Flood Control 11 — Shoreline Erosion
9	12 — Fish and Wildlife
10	13 — Power 14 — Noxious Weeds
11	15 — Biota
12	16 — Hydraulic Model Testing

CHESAPEAKE BAY FUTURE CONDITIONS REPORT

APPENDIX 13

ELECTRIC POWER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

THE STUDY AND THE REPORT

The Chesapeake Bay Study developed through the need for a complete and comprehensive investigation of the use and control of the water and related land resources of Chesapeake Bay. In the first phase of the study, the existing physical, biological, economic, social and environmental conditions and the present problem areas in the Bay were identified and presented in the Chesapeake Bay Existing Conditions Report. The Future Conditions Report, of which this Appendix is a part, presents the findings of the second, or projections phase of the study. As part of this second phase of the study, projections of future needs and problem areas, means to satisfy those needs, and recommendations for future studies and hydraulic model testing were developed for each of the resource categories evaluated. The results of this phase of the study constitute the next step toward the goal of developing a comprehensive water resource management program for Chesapeake Bay.

This volume contains appendices 13 and 14.

Contemporary water and related land resource planning involves analysis of the broadest possible range of prospective development and management plans. Since electric power has come to be such a significant factor in the economic and cultural uses of our resources it carries a major, although generally indirect, impact on area development. This appendix 13 attempts to develop a picture of past and future power development in the study area and to identify the impacts of electric power. Historical progress, present developments, and future needs and potentials are presented. (cont on p. 2 appendix 14)

AUTHORITY

The authority for the Chesapeake Bay Study and the construction of the hydraulic model is contained in Section 312 of the River and Harbor Act of 1965, adopted 27 October 1965.

The supplemental Appropriation Act of 1973, signed by the President on 31 October 1972, included funds for additional studies of the impact of Tropical Storm Agnes on Chesapeake Bay.

The Authority for participation of the Federal Power Commission in the Chesapeake Bay Study is contained in the Federal Power Act, Part I, Section 4, Subsections a and c.

"SEC. 4. (As amended August 26, 1935). The Commission is hereby authorized and empowered--

(a) To make investigations and to collect and record data concerning the utilization of the water resources of any region to be developed,...."

(c) To cooperate with the executive departments and other agencies of State or National Governments in such investigations;.... "

PURPOSE

The Future Conditions Report provides water-land resource planners and other interested parties with an understanding of the available resources in the study area and the multiple, and of the sometimes conflicting, demands to be placed on these resources through the year 2020. Such understanding is necessary for the formation of an adequate water and related land management program as a guide to the intelligent development, enhancement, conservation, preservation and restoration of the Bay's resources. Consideration of electric

power and its effects on the socioeconomic functions of the region is an essential element of such understanding.

SCOPE

The Chesapeake Bay extends in a northerly direction from its junction with the Atlantic Ocean at the Newport News - Northfolk area of Virginia to the mouth of the Susquehanna River near the Pennsylvania - Maryland border.

Examination of the power aspects of the Bay required definition of an appropriate Market Area and suitable sectors within this market for power developed in the Chesapeake Bay study area. The selection of this market and its sectors is described in Chapter II. Historical patterns of electric energy consumption in the Market were analyzed with respect to current developments in the power industry and future power demands in the Market Area were estimated through the year 2020. The generating capacity mix required to supply the estimated demand was developed and its related land and water use was identified. Generating plants were sited and the associated water use identified in the various parts of the Bay through the year 2000 but no such comparable effort was made for facilities required after that period. The degree of uncertainty associated with siting generating plants so far into the future limits discussion to a more general treatment for the latter period. The uncertainty associated with related transmission line requirements dictated a generalized treatment of its land use over the entire study period.

Plans for future power development are based on present technology, with some presumed improvement in efficiency. While it is realistic to conceive that some revolutionary technological changes will take place in the future in the power generating and transmission fields, no attempt has been made in this study to predict what those changes may be. If such changes are to come they would apply to areas outside of as well as within the Chesapeake Bay Region so the relative position of the Region with respect to other

areas would probably not be materially affected. Therefore, the power plant siting indicated through the year 2000 should be considered a characterization of the possible impacts of electric power on particular bodies of water. The placement of future power plants at suitable locations is a process under continuing review and the siting scheme shown will undoubtedly be subject to change as time passes and situations change.

The basic data and general background information used in the analysis have been taken from reports and other documents provided by the electric power industry or prepared by staff of the Federal Power Commission, from economic projections prepared for use in connection with the Chesapeake Bay Existing Conditions Report, and from other available sources.

SUPPORTING STUDIES

Material relevant to the electric utility industry and electric power development in Chesapeake Bay had been incorporated into other supporting studies in the past. Where possible pertinent information from the following studies was utilized in this appendix.

Chesapeake Bay Existing Conditions Report - Appendix B.
U.S. Army Corps of Engineers, North Atlantic Division-1973

"Cumulative Environmental Impact Report"
Maryland Power Plant Siting Program - January 1974

"Second National Assessment"
U.S. Water Resources Council - in progress

"River Basin Planning Status Reports"
Federal Power Commission

"The Nation's Water Resources"
U.S. Water Resources Council - 1968

STUDY PARTICIPATION AND COORDINATION

This Power Appendix was prepared under the auspices of

The Chesapeake Study Group for inclusion in the Chesapeake Bay Future Conditions Report. It was developed by the Federal Power Commission's New York Regional Office staff and reflects communication with other offices of the Federal Power Commission and with utilities in the study area. Within the Chesapeake Bay Study Organization this appendix was reviewed by both the Advisory Group and the Steering Committee.

CHAPTER II

ELECTRIC POWER IN THE CHESAPEAKE BAY REGION

The development of electric power in Chesapeake Bay largely was molded by the geography, economy, and social activity around the Bay. The distribution of population, the character of industry, availability of surface water, and other circumstances proper to Chesapeake Bay all contributed to the pattern by which electric power grew from its infancy in the last century to the major commercial and social institution of today.

DESCRIPTION OF THE REGION

THE CHESAPEAKE BAY REGION

Chesapeake Bay and its tributaries constitute the largest estuarine system in the United States and one of the largest in the world. The Bay has a surface area of about 4,400 square miles (11,400 square kilometers) and a length of nearly 200 miles (320 kilometers). The Bay is oriented in a north-south direction, connecting with the Atlantic Ocean at the southern end. It varies from approximately 4 to 30 miles (6 to 50 kilometers) in width and has an average depth of less than 28 feet (9 meters). The tidal shore line of the Bay is about 7,000 miles (11,000 kilometers) in length with approximately 60 percent lying in Maryland and 40 percent in Virginia.

The Susquehanna River empties into the north end of the Bay, providing approximately 50 percent of the Chesapeake's fresh water supply. The major western tributaries, arising in the Piedmont and the Ridge and Valley Provinces, include the Bush River, Gunpowder River, Patuxent River, Potomac River, Rappahannock River, York River, and James River. The eastern tributaries come down from the Delmarva Penninsula and include the Pocomoke River, Nanticoke River, Choptank River, and Chester River.

On the whole the Bay receives fresh water from a drainage area of some 64,000 square miles (166,000 square kilometers) with the tidal reaches and baylets fringed with marshes. Swamp forests are found on sections of the lower Bay.

The climate is temperate continental and characterized by abundant precipitation, moderate snowfall, plentiful sunshine, and a long frost-free season. Summers tend to be long and humid while winters are variable.

Approximately 7.9 million people inhabited the Bay area in 1970. This total is more than double the 1940 figure and is expected to double again by the year 2020, reaching approximately 16.3 million people. About 80 percent of the people presently live in the metropolitan areas of Washington, Baltimore, Richmond, and Portsmouth and over 50 percent of the total population growth between 1970 and 2020 is expected to take place in the Washington metropolitan area.

As would be expected, the population distribution reflects the economic development. Approximately 3.3 million people were employed in 1970, divided among four major employment categories: the Service Sector (26 percent of total employment) the Wholesale and Retail Trade Sector (17 percent), the Manufacturing Sector (16 percent) and the Public Administration Sector (14 percent). The natural transportation network provided by the Bay and its tributaries played a significant role in the development of the major urban centers of industry and commerce previously mentioned and in concurrent development of electric power in the area. Present and future power supply has been and will be primarily directed toward meeting the residential, commercial, and industrial requirements of these major load centers.

RESOURCES

Only a little over one-third of the land around the Bay is considered developed and most, about 87 percent, of this developed land is in agricultural use. The concentration of people and economic activity is further illustrated by the fact that all land used for residential, commercial, and industrial purposes is less than 5 percent of the total land around the Bay.

The sources of water are the fresh water tributaries of the Bay, ground water from excellent water-bearing sands and gravel that underly the Bay area, and the brackish water of the estuary itself. Because of the variations in salinity levels, the Chesapeake Estuary supports a wide variety of fish life. Wetlands, about 5 percent of the total land area, which are very important to the productivity of the Bay are being lost or threatened by an alarming rate of development. Generally, finfish reproduce in the low saline waters of the Upper Bay and the upstream portions of the tributaries. On the other hand, the famous blue crab reproduces in the saltier waters at the mouth of the Bay. In addition, some species use the Bay as a spawning area and nursery, then migrate to the ocean for their adult life. The most important species from a dollar value standpoint are oysters, crabs, clams, menhaden, and striped bass. The marshes, woodlands, and the Bay itself, provide an extremely productive natural habitat for over 2,700 different species. These marshes and swamp forests are ideal for deer and waterfowl. The area is one of the key areas of the United States for wintering and resting of migratory waterfowl and shorebirds. Several thousand acres of high quality salt marsh are managed by public and private agencies specifically for waterfowl.

The Region also offers a wide variety of water-oriented recreational opportunities. These include an area for fishing, crabbing, sailing, boating, water skiing, canoeing and swimming, picnicking, camping, hiking and even fossil collection. Water quality conditions in the Bay vary widely due to a variety of factors: proximity to urban areas, type and extent of industrial and agricultural activity, stream-flow characteristics, and the amount and type of upstream land and water usage. Most of the water quality problems occur in the estuaries of the Bay's tributaries and not in the Bay proper.

Virtually no commercial fuels or metals are found in the study area, but extensive non-metal mineral deposits, such as sand, gravel, stone, flint, and feldspar, have proven to be of significant value to the development of the Region. For the basin as a whole one of the most economically valuable resource is the building or dimension stone used in the construction industry. Crushed or broken stone is also of considerable value while a great variety of sedimentary clays found in the area are used in sewer pipe, pottery, stoneware, and ceramic products.

HISTORY

The first public application of electricity in the Chesapeake Bay region was to street lighting by arc-lamps, installed in Washington, DC, in 1879. Similar street lighting systems soon followed in Richmond and Baltimore, but due to the maintenance problems associated with arcs, electric street lighting seemed fated to remain a novelty. Nevertheless, new uses for electricity were being explored. Newspapers printed on electric presses appeared in Washington in 1883, and Richmond converted its streetcar system to electric power in 1888.

These early electric services were not available to the general public in any real commercial sense. Public demand for electric service for homes and businesses led to a "subscription" service whereby a fee was assessed for the number of lamps connected to the service lines. Metered service soon followed with billings based on actual kilowatthour usage. By 1900 all the metropolitan cities in the Bay region had generally available electric service for all who desired it and the present arrangement of utilities and territories had been pretty much established.

During the mid-1920's three utilities operating in Pennsylvania and New Jersey undertook studies to determine the justification and need for high-capacity interconnections to realize certain of the benefits of power pooling. The outcome of these studies was the formation of the Pennsylvania-New Jersey Interconnection (PA-NJ Pool). By agreement dated September 16, 1927, Public Service Electric and Gas Company, Philadelphia Electric Company, and Pennsylvania Power & Light Company initiated the construction of 220 KV interconnection lines and also established operations under the "one-system" concept. Under this concept, the members of a power pool are operated as though they were one system, without regard for territorial division or ownership.

As the members grew and as interconnection lines were established with adjacent utilities, more utilities were involved in the operation of the Pennsylvania-New Jersey Interconnection. By agreement dated September 26, 1956, the present Pennsylvania-New Jersey-Maryland Interconnection (PJM Pool) replaced the former PA-NJ Pool. In addition to the original three members, Baltimore Gas and Electric Company, Jersey Central Power & Light Company, Metropolitan Edison Company, New Jersey Power & Light Company, and Pennsylvania Electric Company entered into this agreement. By a supplemental agreement dated January 28, 1965, Potomac Electric Power Company became the ninth signatory to the PJM Agreement. Three additional utilities operate within the PJM Pool through agreements made with their adjacent neighbors: Atlantic City Electric Company, Delmarva Power & Light Company, and UGI Corporation. In 1972, New Jersey Power & Light Company merged into Jersey Central Power & Light Company, and Vineland Municipal in New Jersey joined the PJM, operating in coordination with Atlantic City Electric Company.

The CARVA Pool, comprised of Carolina Power & Light Company, Duke Power Company, South Carolina Electric & Gas Company, and Virginia Electric and Power Company, was formed after several years' planning and negotiation directed toward increasing coordination over the wide geographical area served by the companies. The agreement, which went into full effect on May 1, 1967, was the culmination of efforts begun in 1961 to attain maximum economy and bulk power supply reliability for the benefit of the States of North Carolina, South Carolina, Virginia, and a small part of West Virginia. Under the CARVA agreement, the companies were specifically committed to undertake joint planning and operation of transmission and generation facilities. Implementation of the agreement permitted members to install larger size units with attendant economies in first cost and operation, and this resulted in the the shared development of plans for an extensive Extra High Voltage bulk power transmission system among the Pool companies.

In 1970 the CARVA agreement was replaced by a new compact providing for greater flexibility among the members to enhance bulk power supply and reliability. At the same time three new members were admitted: Yadkin Inc., South Carolina Public Service Authority, and the Southeastern Power Administration, being respectively an industrial, state, and Federal utility. The new agreement constitutes the Virginia-Carolinas (VACAR) Pool.

DESCRIPTIVE PUBLICATIONS

All materials used in the preparation of this Appendix are available through normal sources such as the U.S. Government Printing Office or the Office of Public Information of the Federal Power Commission. These are included in the References section.

PRESENT STATUS

In studying the electric power resources of Chesapeake Bay a geographic area containing the shoreline of the Bay and encompassing the electric utilities serving the Bay was defined. This area, the Chesapeake Bay Market Area, is delineated by the exterior boundaries of those utilities which border on the shores of the Bay.

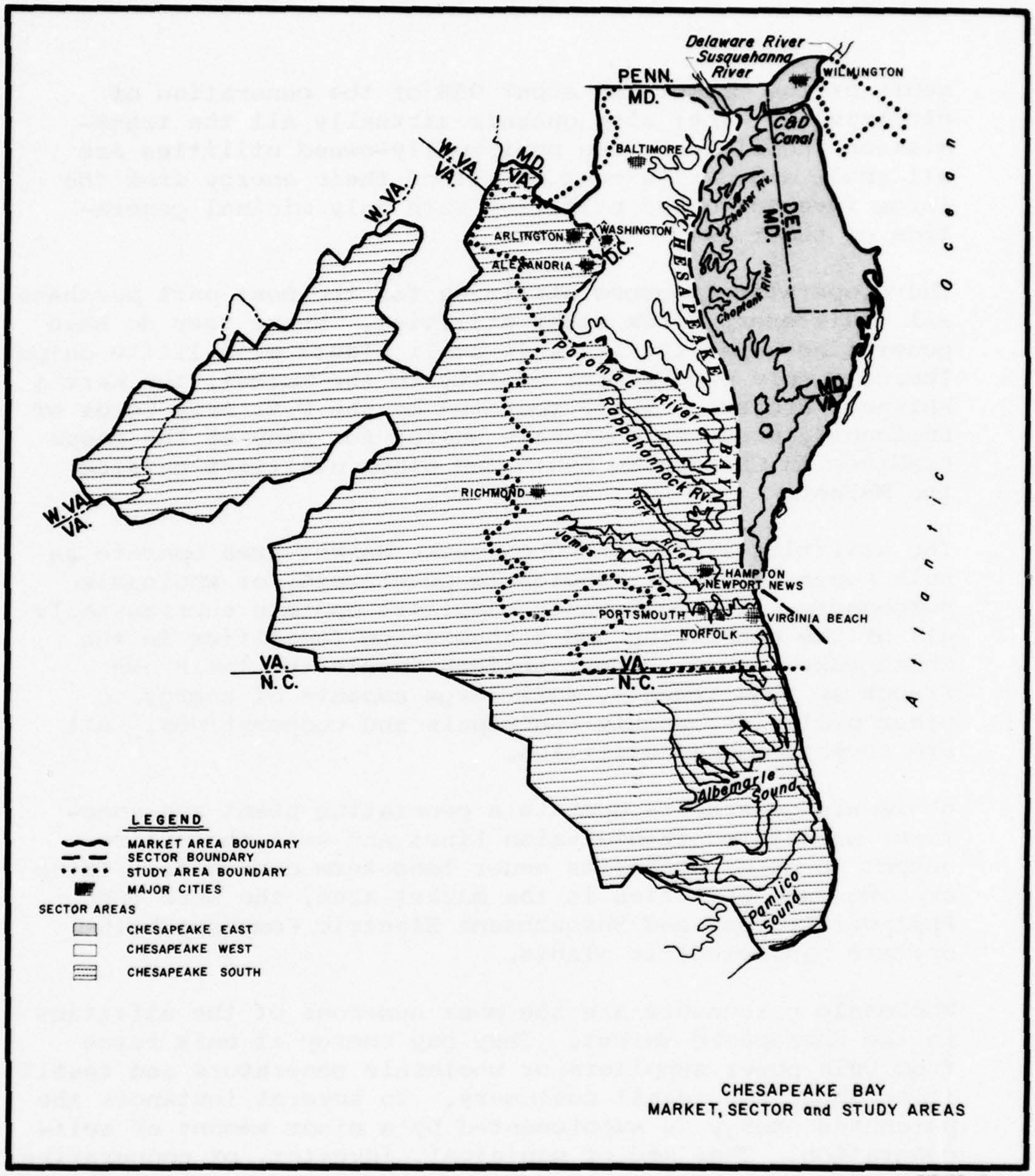
In recognition of the geographical and electrical characteristics of the Market Area utilities, the Market was divided into three Sectors: Chesapeake West, Chesapeake East, and Chesapeake South.

Chesapeake West includes the Baltimore-Washington corridor of the PJM Pool; Chesapeake East takes in the Delmarva Peninsula portion of the PJM Pool; Chesapeake South covers the Virginia area of the VACAR Pool. Figure 13.1 outlines the Market and its sectors.

PRESENT RESOURCE USE

The utilities serving the Chesapeake Market area number 74, ranging in size from Virginia Electric and Power Company with over 26,000 gigawatthours of energy requirements in 1972 to Princeville Municipal (NC) with barely 1 gigawatthour of requirements.

The utilities are of varied ownerships: private corporations, municipalities, consumer cooperatives, and the Federal government. Investor-owned utilities in the Market Area account for almost 90% of the energy require-



CHESAPEAKE BAY
MARKET, SECTOR and STUDY AREAS

FIGURE 13-1

ments of the Market and about 95% of the generation of electricity. They also operate virtually all the transmission facilities. The municipally-owned utilities are all small and derive most or all of their energy from the large investor-owned utilities with only minimal generation of their own.

The cooperatively-owned utilities for the most part purchase all their energy from other utilities. Where they do have generating capacity, it is in small plants with little output. There is only one Federal utility in the Market, the Kerr & Philpott Project. This, operated by the U.S. Army Corps of Engineers, produces wholesale energy for many of the cooperatives in Chesapeake South and other utilities outside the Market.

The utilities within the Chesapeake Market Area operate as bulk power suppliers, wholesale generators, or wholesale purchasers. The bulk power suppliers operate substantially all of the generating and transmission facilities in the Chesapeake Market. They, besides furnishing their own franchise requirements, sell large amounts of energy to other utilities, mainly municipals and cooperatives. All are investor-owned utilities.

Wholesale generators operate a generating plant and sometimes associated transmission lines and sell the entire output to other utilities under long-term contracts. There are two such utilities in the market area, the Kerr and Philpott Project and Susquehanna Electric Company; both operate hydroelectric plants.

Wholesale purchasers are the most numerous of the utilities in the Chesapeake Market. They buy energy at bulk rates from bulk power suppliers or wholesale generators and resell it to their own retail customers. In several instances the purchased energy is supplemented by a minor amount of self-generation. They are of municipal, investor, or cooperative ownerships.

Table 13.1 lists all the Market utilities with their generation and energy requirements for 1972 as well as the Sector of the Market Area they serve.

Table 13-1

Electric Utilities In The Chesapeake Bay Market, 1972

Utility	Type of Ownership	Annual Generation GWh	Energy Requirements GWh
Chesapeake West			
Baltimore G&E	Investor	12237	14009
Potomac El. Pr.	Investor	20074	13567
		32311	27576
Southern Maryland	Cooperative	0	676
		0	676
		32311	28252
Chesapeake East			
Delmarva P&L	Investor	5512	4455
Delmarva P&L MD	Investor	849	1033
Conowingo Pr.	Investor	0	360
Delmarva P&L VA	Investor	22	167
Chestertown EL&P	Investor	0	59
Susquehanna El.	Investor	2243	19
Stockton L&P	Investor	0	10
Lincoln & Ellendale	Investor	0	7
		8626	6110
Dover, DE	Municipal	155	334
Newark, DE	Municipal	0	153
Easton, MD	Municipal	75	75
Milford, DE	Municipal	0	60
Seaford, DE	Municipal	0	40
Centreville, MD	Municipal	0	28
Lewes, DE	Municipal	9	27
Smyrna, DE	Municipal	0	25
St. Michaels, MD	Municipal	0	24
Berlin, MD	Municipal	8	22
New Castle, DE	Municipal	0	14
Middletown, DE	Municipal	0	11
Clayton, DE	Municipal	0	4
		247	817
Delaware	Cooperative	0	196
Choptank	Cooperative	0	185
Accomack-Northampton	Cooperative	3	62
		3	443
		8876	7370

Table 13-1 (Cont'd)

Electric Utilities In The Chesapeake Bay Market, 1972

Utility	Type of Ownership	Annual Generation GWh	Energy Requirements GWh
Chesapeake South			
Virginia E&P	Investor	25709	26189
Pamlico P&L	Investor	0	17
Crist Pr.	Investor	0	1
		25709	26207
Greenville, NC	Municipal	0	386
Harrisonburg, VA	Municipal	0	185
Washington, NC	Municipal	0	158
Tarboro, NC	Municipal	0	135
Elizabeth City, NC	Municipal	0	129
Franklin, VA	Municipal	0	58
Edenton, NC	Municipal	0	44
Manassas, VA	Municipal	0	44
Blackstone, VA	Municipal	0	21
Scotland Neck, NC	Municipal	0	19
Enfield, NC	Municipal	0	18
Windsor, NC	Municipal	0	18
Culpeper, VA	Municipal	5	17
Robersonville, NC	Municipal	0	12
Hertford, NC	Municipal	0	11
Belhaven, NC	Municipal	0	10
Elkton, VA	Municipal	0	10
Wakefield, VA	Municipal	0	6
Hobgood, NC	Municipal	0	3
Oak City, NC	Municipal	0	2
Hamilton, NC	Municipal	0	2
Iron Gate, VA	Municipal	0	1
Princeville, NC	Municipal	0	1
		5	1290
Prince William	Cooperative	0	321
Virginia	Cooperative	0	281
Southside	Cooperative	0	235
Shenandoah Valley	Cooperative	0	178
Mechklenburg	Cooperative	0	169
Northern Piedmont	Cooperative	0	88
Roanoke	Cooperative	0	70
B.A.R.C.	Cooperative	1	63
Northern Neck	Cooperative	0	63
Tideland	Cooperative	0	60
Edgecombe-Martin	Cooperative	0	56
Community	Cooperative	0	54
Central Virginia	Cooperative	0	133

Table 13-1 (Cont'd)

Electric Utilities In The Chesapeake Bay Market, 1972

Utility	Type of Ownership	Annual Generation Gwh	Energy Requirements Gwh
Chesapeake South (Cont'd)			
Tri-County	Cooperative	0	42
Prince George	Cooperative	0	41
Halifax	Cooperative	0	40
Albemarle	Cooperative	0	38
Craig-Botetourt	Cooperative	1	26
Cape Hatteras	Cooperative	/1	17
Ocracoke	Cooperative	/1	2
		2	1977
Kerr & Philpott	Federal	698	0
		698	0
		26414	29474
TOTAL CHESAPEAKE MARKET AREA		67601	65096

/1 Less than 1.

MARKET SECTORS

The Market Sectors display varied compositions of utilities by site, number, ownership, and operation. But for all their diversity, the Sectors can be adequately described and characterized by considering just four utilities Delmarva P&L Co. for Chesapeake East, Baltimore G&E Co. and Potomac El Pr. Co. for Chesapeake West, and Virginia E&P Co. for Chesapeake South. Together these four account for over 89% of the Market's energy requirements and almost 94% of its generation. A brief description of each Sector follows.

a. CHESAPEAKE WEST. Chesapeake West has 3 utilities: Potomac Electric Power Company, Baltimore Gas and Electric Company, and Southern Maryland Electric Cooperative. The energy requirements of Chesapeake West in 1972 were 28,252 gigawatthours balanced against a generation of 32,311 gigawatthours. The excess generation was almost entirely delivered to more northernly members of the PJM Pool outside the Chesapeake Bay Market with only minor amounts flowing into Chesapeake South. The generating facilities were all in investor-owned utilities and consisted of 7,000 megawatts in fossil steam plants and 1,113 megawatts in combustion plants*. Southern Maryland Electric Coop. purchases its entire needs from Potomac Electric Power Company. It is the largest cooperative in the Market with energy requirements in 1972 of 676 gigawatthours.

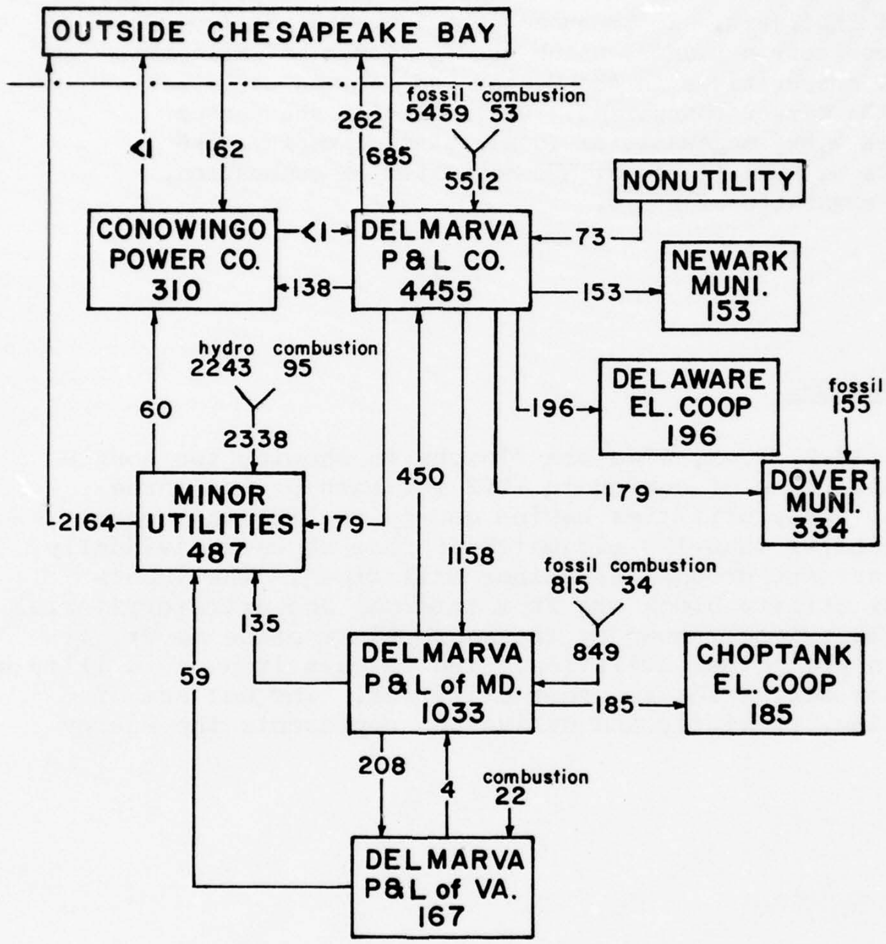
b. CHESAPEAKE EAST. Chesapeake East has 24 utilities: 8 investor-owned, 13 municipally-owned, and 3 cooperatives. The largest investor-owned utility, Delmarva Power & Light Company, alone accounts for more than half of the Sector's energy and about 2/3 of its generation. The Sector's energy requirement in 1972 was 7,370 gigawatthours and generation was 8,876 gigawatthours making it the smallest of the three sectors. The sector's generating capacity consisted of 1,294 megawatts in fossil steam capacity, 209 megawatts in combustion capacity, and 474 megawatts in a single hydroelectric plant. Easton Municipal, the Market's only isolated utility, is located in Chesapeake East. Easton's entire energy requirements of 75 gigawatthours in 1972 were furnished by its 23 megawatt combustion plant. The bulk of the excess generation came from the hydroelectric plant, Conowingo, and was delivered to the more northernly parts of the PJM Pool beyond the market boundaries.

*Plants which do not use steam as an intermediary between the burning of fossil fuel and the production of electricity.

c. CHESAPEAKE SOUTH. Three investor utilities, 23 municipals, 20 cooperatives, and one Federally operated project constitute the 47 utilities of Chesapeake South, which in 1972 had an energy requirement of 29,474 gigawatthours. When balanced against a generation of 26,414 gigawatthours, Chesapeake South had a modest net import, almost entirely from outside the Market. Virginia Electric and Power Company with about 90% of both energy and generation is the major utility in Chesapeake South. The only other significant generation in the sector is that from the Kerr and Philpott Project of the Corps of Engineers. It produced 698 gigawatthours from its two hydroelectric plants, which was delivered at wholesale rates to cooperatives in the Sector and certain utilities beyond the Market boundaries. On the whole, the sector contained 4,597 megawatts of fossil steam capacity, 848 megawatts of nuclear steam, 573 megawatts of combustion, and 506 megawatts of hydro.

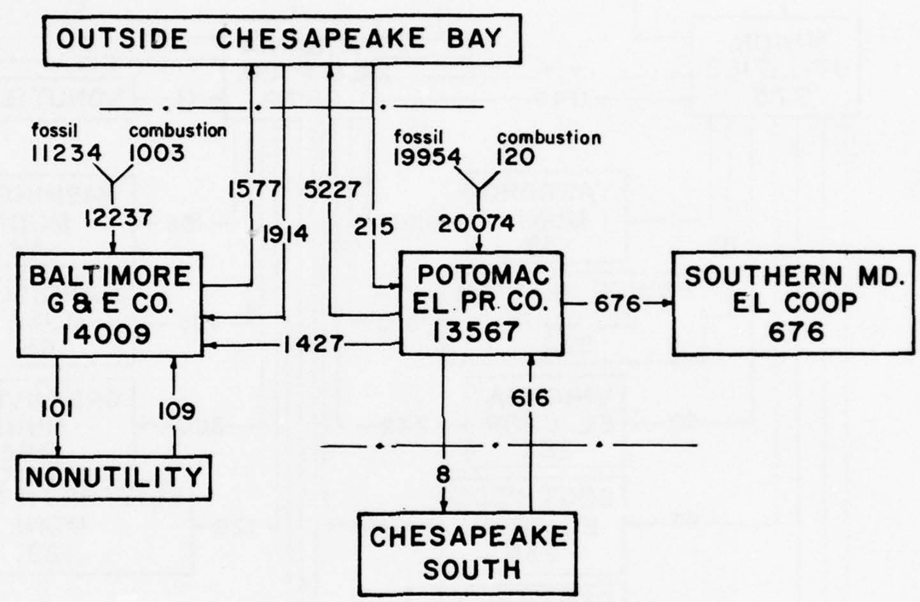
ENERGY ACCOUNT.

Figures 13-2, 13-3, 13-4 are flowcharts showing the source and disposition of energy in 1972 for each of the three Sectors. Only utilities having energy requirements equal to or greater than 100 gigawatthours are shown individually. All others are grouped as "Minor Utilities". The inputs into any utility block are from internal and extraterritorial owned generation, shown by the appropriate prime mover, or receipts from other utilities. The outputs from any utility's block are deliveries to other utilities. The net sum of generation, receipts, and deliveries represents the energy



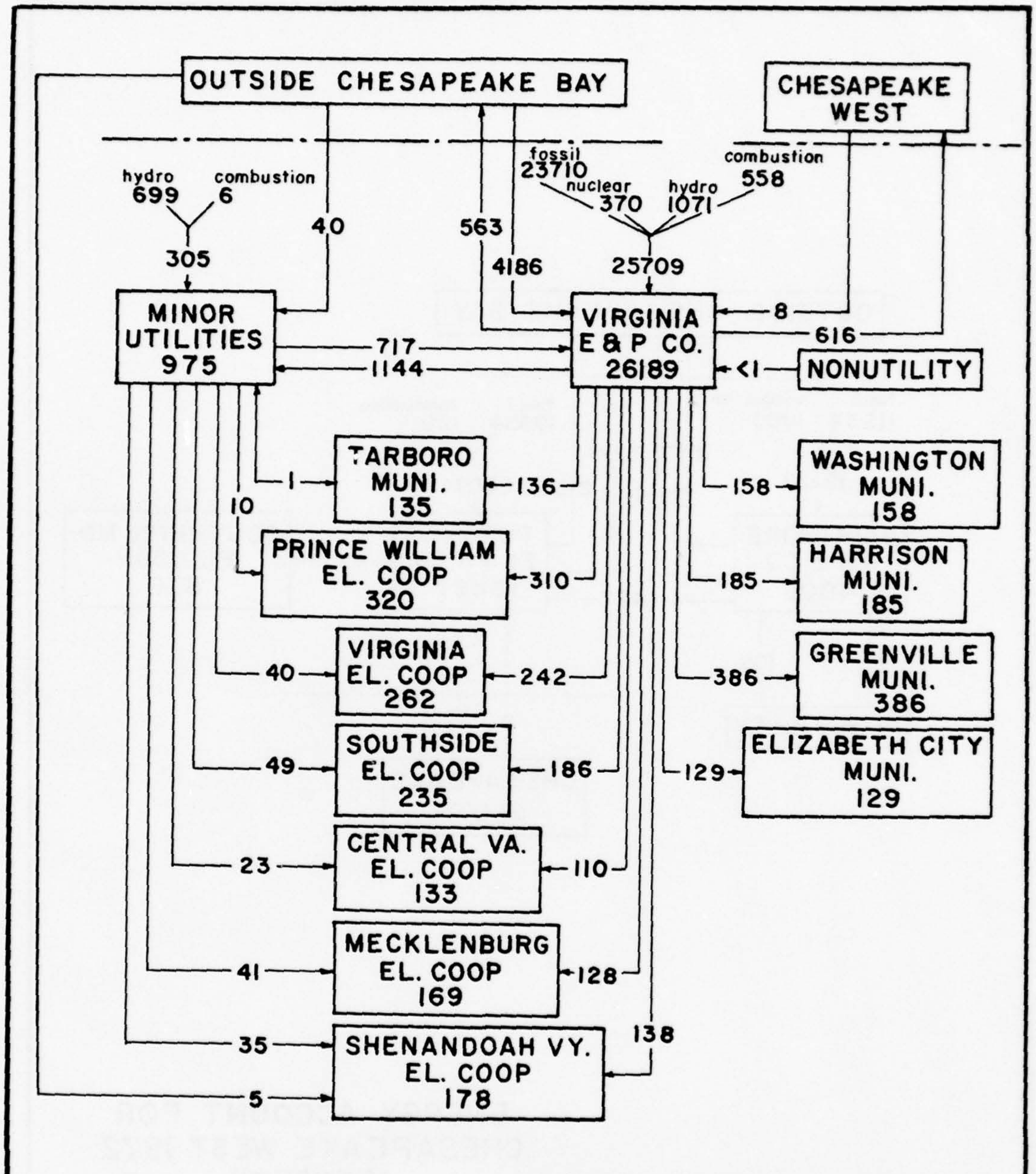
ENERGY ACCOUNT FOR CHESAPEAKE EAST 1972
(gigawatthours)

Figure 13-2



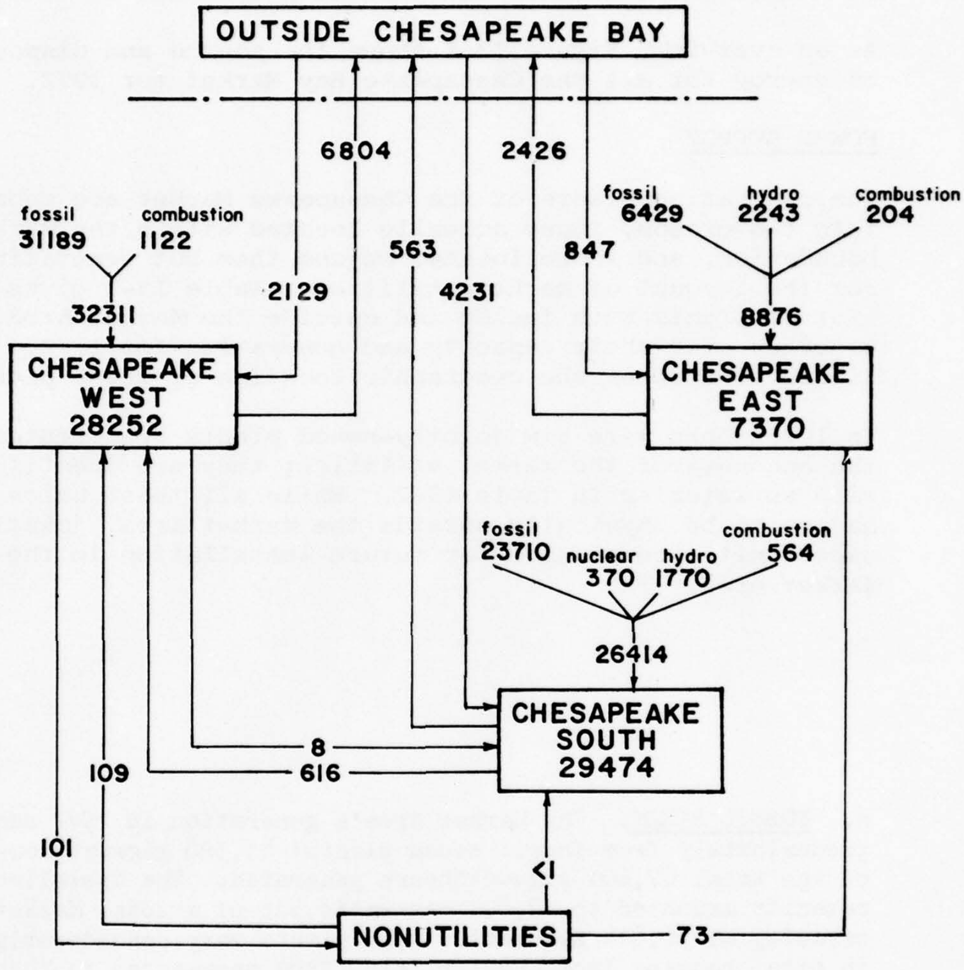
ENERGY ACCOUNT FOR
CHESAPEAKE WEST 1972
(gigawatthours)

Figure 13–3



ENERGY ACCOUNT FOR CHESAPEAKE SOUTH 1972
(gigawatthours)

Figure 13-4



ENERGY ACCOUNT FOR CHESAPEAKE BAY MARKET AREA 1972
(gigawatthours)

Figure 13-5

requirements for the utility. This energy is distributed to the utility's ultimate retail customers, internal utility use, free service, and losses. The total amount is indicated within the block beneath the name of the utility.

As an overview, Figure 13-5 shows the source and disposition of energy for all the Chesapeake Bay Market for 1972.

POWER SUPPLY

The generating plants of the Chesapeake Market are separated into two groups, those actually located within the Market boundaries, and those located beyond them but generating for the account of market utilities. Table 13-2 gives a list of plants both inside and outside the Market Area, together with their capacity and generation for 1972. Figure 13-6 shows the geographic location of these plants.

In 1972 there were six jointly-owned plants represented in the accounts of the market utilities; they are identified with an asterisk in Table 13-2. While all these units happen to be physically outside the Market Area, jointly-owned units are planned for future installation in the Market Area.

a. FOSSIL STEAM. The Market Area's generation in 1972 came predominately from fossil steam plants: 61,328 gigawatthours of the total 67,601 gigawatthours generated. The installed capacity amounted to 12,891 megawatts out of a total Market capacity of 16,614 megawatts. The plants vary considerably in size, ranging from Chesterfield (1484 megawatts) to McKee Run, (38 megawatts). All are owned by the investor-owned utilities with the exception of the McKee Run plant which is owned by Dover Municipal in Delaware.

b. NUCLEAR STEAM. The first nuclear steam plant in the

Table 13-2

Utility Generating Plants In The Chesapeake Bay Market, 1972

Plant	Utility	Type	Location	Capacity MW	Generation GWh
Chesapeake West					
Morgantown	Potomac El. Pr.	Fossil	Newburg, MD	1251	6900
Wagner	Baltimore G&E	Fossil	Ann Arundel Co., MD	1043	3731
Benning	Potomac El. Pr.	Fossil	Benning, DC	748	2151
Chalk Point	Potomac El. Pr.	Fossil	Brandywine, MD	728	3403
Dickerson**	Potomac El. Pr.	Fossil	Dickerson, MD	586	3626
Potomac River	Potomac El. Pr.	Fossil	Alexandria, VA	499	2511
Crane	Baltimore G&E	Fossil	Baltimore Co., MD.	400	2136
Keystone*, **	Baltimore G&E	Fossil	Shelocta, PA	393	1751
Riverside	Baltimore G&E	Fossil	Baltimore Co., MD	334	1344
Buzzard Point	Potomac El. Pr.	Combustion	Washington, DC	288	92
Buzzard Point	Potomac El. Pr.	Fossil	Washington, DC	270	492
Perryman	Baltimore G&E	Combustion	Harford Co., MD	213	227
Conemaugh*, **	Baltimore G&E	Fossil	New Florence, PA	198	947
Westport	Baltimore G&E	Fossil	Baltimore City, MD	194	651
Conemaugh*, **	Potomac El. Pr.	Fossil	New Florence, PA	182	871
Gould Street	Baltimore G&E	Fossil	Baltimore City, MD	174	674
Riverside	Baltimore G&E	Combustion	Baltimore Co., MD	172	134
Notch Cliff	Baltimore G&E	Combustion	Baltimore Co., MD	144	382
Westport	Blatimore G&E	Combustion	Baltimore City, MD	122	95
Philadelphia Road	Baltimore G&E	Combustion	Baltimore City, MD	70	109
Morgantown	Potomac El. Pr.	Combustion	Newburg, MD	36	14
Chalk Point	Potomac El. Pr.	Combustion	Brandywine, MD	16	9
Crane	Baltimore G&E	Combustion	Baltimore, Co., MD	16	26
Wagner	Baltimore G&E	Combustion	Ann Arundel Co., MD	16	28
Dickerson**	Potomac El. Pr.	Combustion	Dickerson, MD	16	4
Keystone*, **	Baltimore G&E	Combustion	Shelocta, PA	2	1
Conemaugh*, **	Potomac El. Pr.	Combustion	New Florence, PA	1	1
Conemaugh*, **	Baltimore G&E	Combustion	New Florence, PA	1	1
Pratt Street	Baltimore G&E	Fossil	Baltimore City, MD	Retired	/1
				8113	32311
Chesapeake East					
Conowingo	Susquehanna El.	Hydro	Conowingo, PA	474	2243
Edge Moor	Delmarva P&L	Fossil	Edge Moor, DE	390	2175
Indian River	Delmarva P&L	Fossil	Millsboro, DE	340	2160

Table 13-2 (Cont'd)

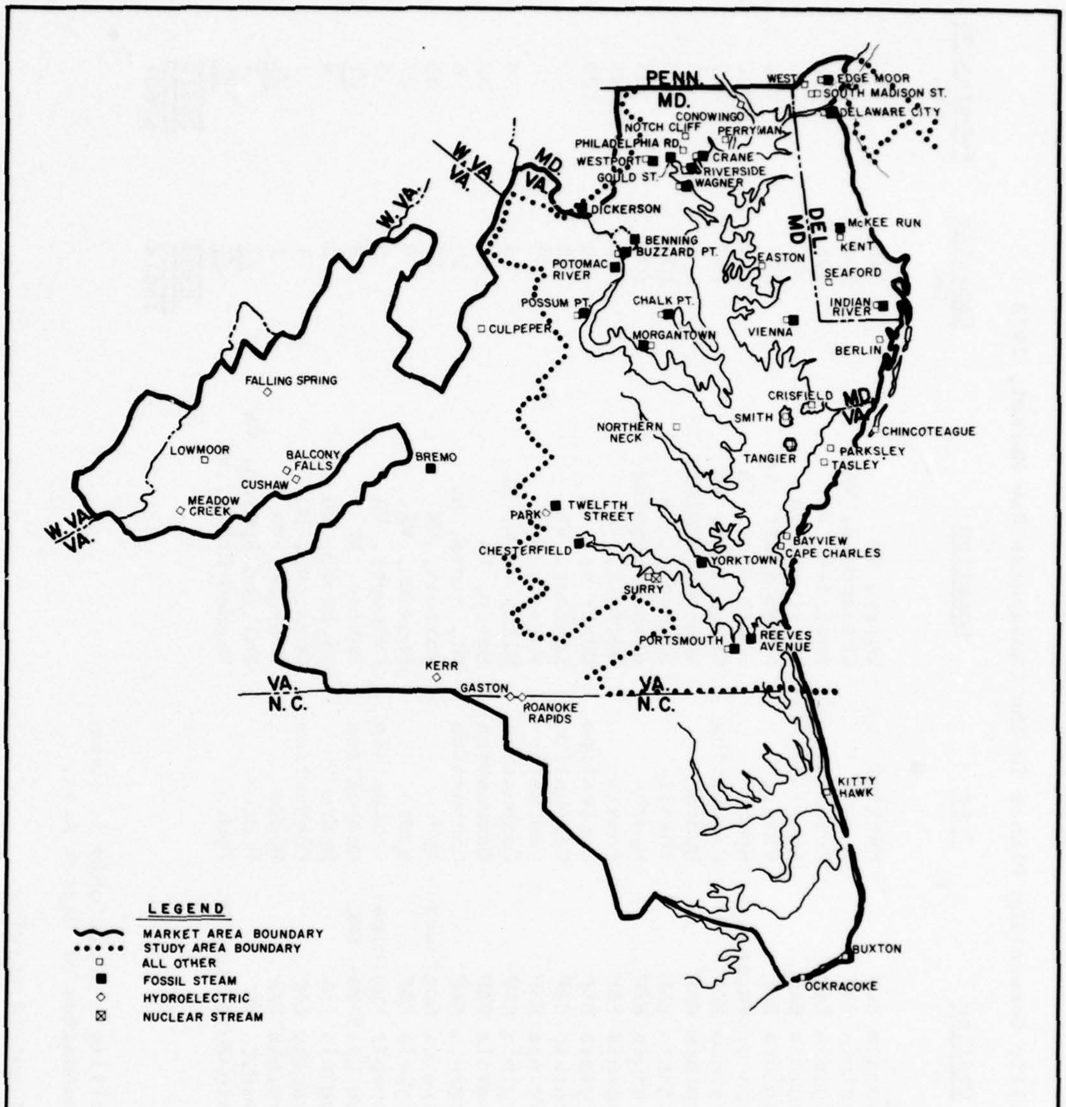
Plant	Utility	Type	Location	Capacity MW	Generation GWh
Chesapeake East (Cont'd)					
Vienna	Delmarva P&L MD	Fossil	Vienna, MD	257	815
Delaware	Delmarva P&L	Fossil	Delaware City, DE	130	481
Conemaugh*, **	Delmarva P&L	Fossil	New Florence, PA	70	334
Keystone*, **	Delmarva P&L	Fossil	Shelocta, PA	69	309
McKee Run	Dover Municipal	Fossil	Dover, DE	38	155
Tasley	Delmarva P&L VA	Combustion	Tasley, VA	27	6
Easton	Baston Municipal	Combustion	Easton, MD	23	75
Delaware	Delmarva P&L	Combustion	Delaware City, DE	19	11
Indian River	Delmarva P&L	Combustion	Millsboro, DE	19	10
Vienna	Delmarva P&L MD	Combustion	Vienna, MD	19	18
West	Delmarva P&L	Combustion	Marshalltown, DE	16	13
Kent	Delmarva P&L	Combustion	Dover, DE	14	4
Edge Moor	Delmarva P&L	Combustion	Edge Moor, DE	13	10
South Madison St.	Delmarva P&L	Combustion	Wilmington, DE	12	3
Crisfield	Delmarva P&L MD	Combustion	Crisfield, MD	11	16
Bayview	Delmarva P&L VA	Combustion	Cape Charles, VA	10	15
Seaford	Seaford Municipal	Combustion	Seaford, DE	7	0
Berlin	Berlin Municipal	Combustion	Berlin, MD	4	7
Lewes	Lewes Municipal	Combustion	Lewes, DE	3	9
Salem*, **	Delmarva P&L	Combustion	Lower Alloways Ck., NJ	3	2
Parksley	Accomack - N EC	Combustion	Parksley, VA	2	/1
Cape Charles	Delmarva P&L VA	Combustion	Cape Charles, VA	2	/1
Chincoteague	Delmarva P&L VA	Combustion	Chincoteague, VA	2	1
Tasley	Delmarva P&L VA	Combustion	Tasley, VA	1	/1
Smith	Accomack - N EC	Combustion	Ewell, VA	1	2
South Madison St.	Delmarva P&L	Combustion	Wilmington, DE	1	/1
Tangier	Accomack - N EC	Combustion	Tangier, VA	/1	2
Conemaugh*, **	Delmarva P&L	Combustion	New Florence, PA	/1	/1
Keystone*, **	Delmarva P&L	Combustion	Shelocta, PA	/1	/1
Peach Bottom *, **	Delmarva P&L	Combustion	Peach Bottom, PA	/2	/1
				1977	8876
Chesapeake South					
Chesterfield	Virginia E&P	Fossil	Chester, VA	1484	8145
Mt. Storm**	Virginia E&P	Fossil	Mt. Storm, WV	1140	6261

Table 13-2 (Cont'd)

Utility Generating Plants In The Chesapeake Bay Market, 1972

Plant	Utility	Type	Location	Capacity MW	Generation GWh
Chesapeake South (Cont'd)					
Surry	Virginia E&P	Nuclear	Surry, VA	848	370
Portsmouth	Virginia E&P	Fossil	Chesapeake, VA	650	3156
Possum Point	Virginia E&P	Fossil	Dumfries, VA	491	2942
Yorktown	Virginia E&P	Fossil	Yorktown, VA	375	2200
Bremo	Virginia E&P	Fossil	Bremo Bluff, VA	254	754
Kerr	Corps of Engineers	Hydro	South Hill, VA	204	662
Portsmouth	Virginia E&P	Combustion	Chesapeake, VA	195	212
Gaston	Virginia E&P	Hydro	Roanoke Rapids, VA	178	505
Twelfth Street	Virginia E&P	Fossil	Richmond, VA	103	65
Roanoke Rapids	Virginia E&P	Hydro	Roanoke Rapids, VA	100	535
Reeves Avenue	Virginia E&P	Fossil	Norfolk, VA	100	187
Possum Point	Virginia E&P	Combustion	Dumfries, VA	96	129
Lowmoor	Virginia E&P	Combustion	Lowmoor, VA	83	79
Northern Neck	Virginia E&P	Combustion	Warsaw, VA	83	76
Kitty Hawk	Virginia E&P	Combustion	Kitty Hawk, NC	48	24
Surry	Virginia E&P	Combustion	Surry, VA	40	32
Mt. Storm	Virginia E&P	Combustion	Mt. Storm, WV	19	6
Philpott**	Corps of Engineers	Hydro	Bassett, VA	13	36
Cushaw	Virginia E&P	Hydro	Snowden, VA	8	27
Culpeper	Culpeper Municipal	Combustion	Culpeper, VA	5	5
Buxton	Cape Hatteras EMC	Combustion	Buxton, NC	3	/1
Park	Virginia E&P	Hydro	Richmond, VA	2	4
Ocracoke	Ocracoke EMC	Combustion	Ocracoke, NC	1	1
Balcony Falls	Virginia E&P	Hydro	Glasgow, VA	1	/1
Falling Spring	B.A.R.C. EC	Hydro	Falling Spring, VA	/1	1
Meadow Creek	Craig-Botetourt EC	Hydro	Meadow Creek, VA	/1	/1
				6524	26414
				16614	67601

*Jointly-owned plant; utility's share only is shown.
**Plant located beyond boundaries of Market Area.
/1 Less than 1.
/2 Test generation; unit not in service.



CHESAPEAKE BAY
PLANT LOCATION MAP
1972

FIGURE 13-6

Chesapeake Bay Market, Surry of Virginia E&P Co. with a capacity of 848 megawatts, went into service late in 1972. In 1973, the first full year of service, Surry generated 6,857 gigawatthours and was connected to the utility's network for 7,801 of the 8,760 hours of the year.

From this modest beginning, utilities serving the Market are planning considerable nuclear capacity in the coming years. In 1972 there were 3 nuclear steam plants under construction: Calvert Cliffs of Baltimore G&E Co., North Anna of Virginia E&P Co., and additional units at Surry. Calvert Cliffs and an additional unit of Surry have since gone into operation and in the decades to come, generation from nuclear steam plants will provide a larger and larger portion of the Market's needs.

c. COMBUSTION. Combustion plants refer to those plants which do not use steam as an intermediary between the burning of fossil fuel and the production of electricity. In the Chesapeake Bay Market combustion plants are of two kinds, the Diesel engine-generator and the gas-turbine engine-generator.

Combustion plants in the Market range from the 288-megawatt Buzzard Point plant of Potomac El. Pr. Co. to the Accomack-Northampton El. Coop. 615-kilowatt Tangier plant. Combustion plants are found on utilities of every size and of every ownership except Federal.

Because they are relatively small self-contained units, combustion plants are generally easily sited anywhere within a utility's territory. On the smaller utilities, Diesel combustion plants generally provide base-load requirements, supplementing outside purchases. On larger utilities, whose base-load generation comes from fossil or nuclear steam plants, the combustion turbine units serve mainly for peak-load and for insuring adequate reserves.

In recent years lengthy delays in construction have been encountered by fossil and nuclear plants in the PJM part of the Chesapeake Market. In matching the ever-increasing demands for electricity, utilities have installed considerable

gas turbine capacity which has a much shorter lead time than either fossil or nuclear. There is a concentration of the larger combustion plants in Chesapeake West, examplified by the Buzzard Point, Perryman, and Riverside plants. Large blocks of combustion plant capacity were under construction in 1972 at the site of the Morgantown fossil steam plant. When completed in 1973 this new plant included 297 megawatts of combustion capacity, and was the largest such plant in the Chesapeake Market.

d. <u>HYDROELECTRIC</u>. Hydroelectric capacity in the Chesapeake Market is concentrated in three large plants: Conowingo, Kerr, and Gaston, these accounting for 856 of the Market's 888 megawatts total hydro capacity in 1972. The Conowingo plant, 474 megawatts is located on the main stream of the Susquehanna River 9 miles (15 kilometers) from its mouth. It furnishes wholesale energy to Conowingo Power Company and Philadelphia Electric Company, the latter being outside the Market. Kerr, 204 megawatts, is operated by the Corps of Engineers to deliver wholesale energy to cooperatives in Chesapeake South. All the remaining hydro capacity, including Gaston, 178 megawatts, is located in Chesapeake South.

Chesapeake South has the bulk of hydroelectric facilities owned by nonutilities - mills, factories, and the like - which produce energy for self-consumption. All these nonutility plants are small, none larger than 3 megawatts.

Table 13-3 gives the characteristics of the Market hydroelectric plants, utility and nonutility. No further development of hydroelectric potential is anticipated by any Chesapeake Market utility and no plans to abandon any existing plants have been announced.

No pumped storage plants were in operation or under construction in the Chesapeake Market in 1972 and only one was scheduled for future installation. This is the 2,100 megawatt Bath County project of Virginia Electric and Power Company, located on the Jackson River near Warm Springs, Va. This site is well outside the Chesapeake Bay tidal area, in the extreme western part of Virginia. Due to the absence of feasible sites in the Chesapeake Bay tidal area, pumped storage projects serving the Market will be located some distance from the Bay itself.

Table 13-3

Hydroelectric Developments In The Chesapeake Bay Market, 1972

Development	Owner	FPC Lic. No.	River	Capacity MW	Avg. Ann. Generation GWh	Storage KAF;Km^3	Gross Head ft;m
	Utilities						
Conowingo	Susquehanna El. Co.	405	Susquehanna Rv.	474	1719	71;0.088	89; 27.1
Park	Virginia E&P Co.	-	James Rv.	2	12	0;0	37; 11.3
Cushaw	Virginia E&P Co.	-	James Rv.	8	28	0;0	27; 8.2
Balcony Falls	Virginia E&P Co.	-	James Rv.	1	5	0;0	15; 4.6
Meadow Creek	Craig-Botetourt EC	-	Meadow Cr.	<1	2	0;0	606;184.7
Falling Springs	B.A.R.C. EC	-	Falling Springs Cr.	<1	1	0;0	515;157.0
Roanoke Rapids	Virginia E&P Co.	2009	Roanoke Rv.	100	315	38;0.047	86; 26.2
Gaston	Virginia E&P Co.	2009	Roanoke Rv.	178	340	95;0.117	68; 20.7
Kerr	Corps of Engineers	-	Roanoke Rv.	204	416	1046;1.290	100; 30.5
	Nonutilities						
Della	WJ Dickey & Sons	-	Patapsco Rv.	1	4	0;0	43; 13.1
Dalecarlia	Corps of Engineers	-	Potomac Rv. Canal	3	5	5;0.006	140; 42.7
Hollywood	City of Richmond	-	James Rv.	2	21	5;0.006	19; 5.8
Byra Park	City of Richmond	-	James Rv.	1	8	5;0.006	19; 5.8
Schuyler	Georgia-Marble Co.	-	Rockfish Cr.	1	1	0;0	32; 9.8

MW=megawatt
GWh=gigawatthour
KAF=thousand acre-feet
ft=feet
m=meters
Km^{3}cubic kilometers

FUELS USE

The fossil steam generation by the Chesapeake Market Area was produced from coal, oil, and gas, with gas being only a very minor contributor. The tabulation below gives the percent contribution to the fossil steam generation for 1972 in each of the sectors.

PERCENT CONTRIBUTION TO FOSSIL STEAM GENERATION, 1972

Sector	Coal	Oil	Gas
Chesapeake East	40	57	3
Chesapeake West	50	50	0
Chesapeake South	29	71	0
Chesapeake Market	40	60	less than 1

In Chesapeake West, plants are about evenly divided between those burning coal only, oil only, and both coal and oil. Except for Indian River and Vienna, plants in Chesapeake East all burn some gas in combination with coal or oil. Mt. Storm is the major consumer of coal in Chesapeake South, the other plants using only minor amounts with oil.

NONUTILITIES

Electric power in the Market is virtually the exclusive product of the electric utility industry, but there are many industrial and commercial concerns which operate generating plants for their own internal energy requirements. All such plants are small and the combined generation from them is miniscule against the total utility generation. Some of these nonutility plants are hydroelectric facilities and are listed in Table 13-3 to give complete coverage to the development of hydroelectric power in the Market.

A few nonutilities have made arrangements with the local utility for the selling of any excess generation they produce in the normal course of their business. The utility reciprocates by supplying the nonutility with energy during periods of deficiency. This interchange of energy benefits all three sectors as depicted in the energy accounts, Figure 13.3 through 13.6.

TRANSMISSION

Of the power lines located within the Chesapeake Bay Market, those operated at 138 kilovolts and higher serve for the transmission of bulk power throughout the region.

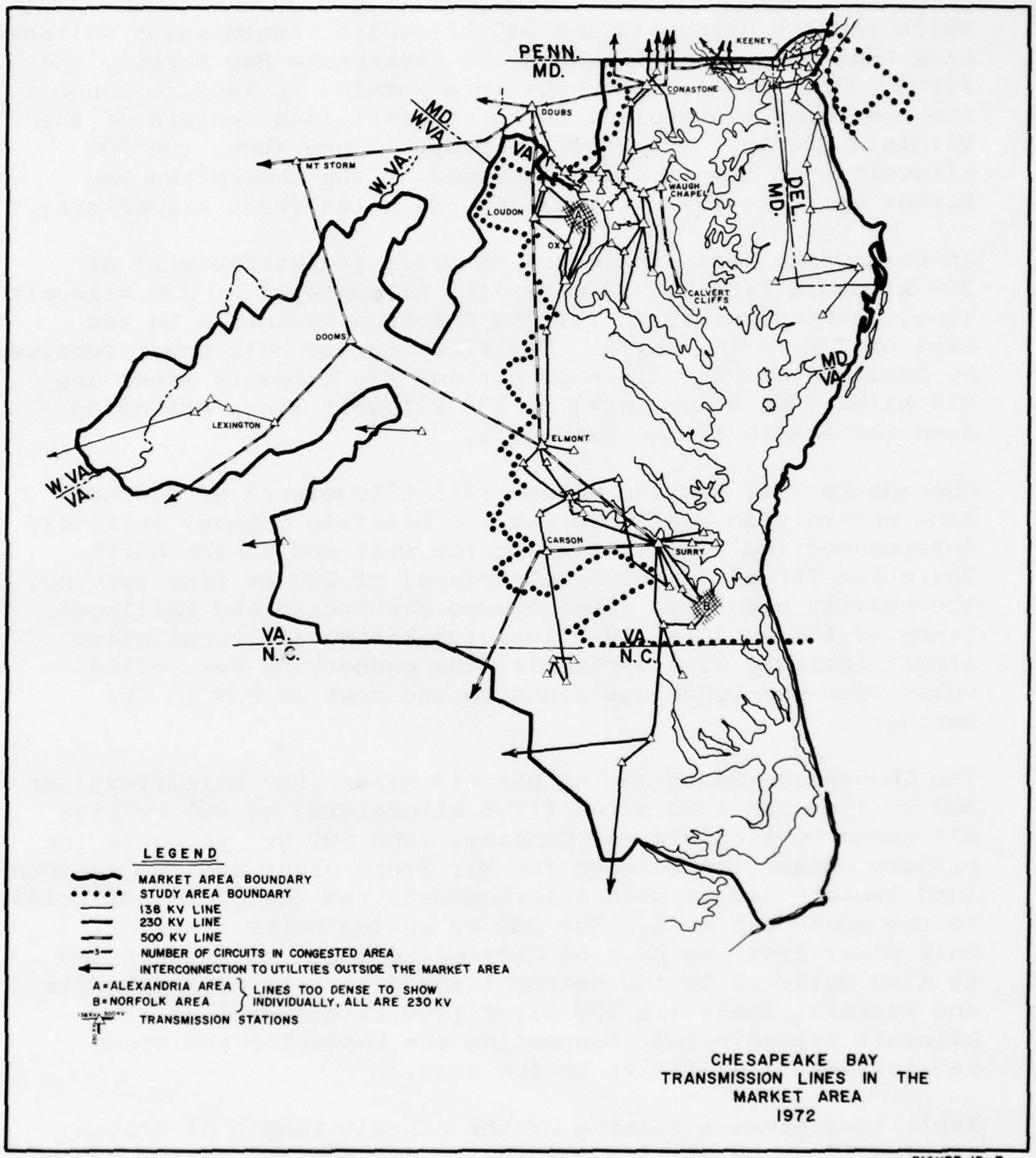
While the 138 kilovolts and 230 kilovolts transmission voltages have been long established in the Chesapeake Bay Market, the first 500 kilovolts line went into service in 1965 to connect the new Mount Storm plant to the coastal load centers of the Virginia Electric and Power Company. Since then, the 500 kilovolt grid has steadily expanded in the Chesapeake Bay Market until in 1972 it totalled 836 miles (1346 kilometers).

In Chesapeake East, there are 28 miles (44 kilometers) of 500 kilovolt line and 39 miles (63 kilometers) of 230 kilovolt line, serving mainly to tie the Delmarva Peninsula to the rest of PJM to the north. Distributing the bulk power received by Delmarva via the 500 kilovolt and 230 kilovolt links are 315 miles (508 kilometers) of 138 kilovolt line, extending down the length of the Peninsula.

Chesapeake West has 196 miles (315 kilometers) of 500 kv line entirely in Baltimore Gas and Electric Company territory interconnecting to utilities to the west and to the north. There are 736 miles (1184 kilometers) of 230 kv line serving the heavily populated zones around Washington and Baltimore. Lines of 138 kv total 58 miles, (93 kilometers) consisting almost entirely of a 4-circuit line connecting Perryville substation and Conowingo plant to the rest of PJM to the north.

The Chesapeake South sector has 613 miles (987 kilometers) of 500 kv line and 1060 miles (1705 kilometers) of 230 kv line all owned by Virginia E&P Company. The 500 kv system is the primary connection between the Mt. Storm plant and the eastern load centers and it also interconnects the Sector to utilities to the south and west. The 230 kv system helps transfer bulk power from one part of Chesapeake South to another and it also delivers to the metropolitan districts of Alexandria and Norfolk. There are 105 miles (169 kilometers) of 138 kilovolt transmission, connecting the Lexington and Bremo substations to utilities to the west.

Table 13-4 gives a listing of the circuit length of transmission lines by utility for 1972. All the 500 kv and 230 kv lines are supported by steel towers. The 138 kv lines are supported by wood frames, although steel poles and towers are occasionally used. Within the center city districts of Washington and Baltimore, transmission lines are placed underground. These lines, all 138 kv, amount to 131 miles (211 kilometers) and are not included in the Table. Figure 13.7 is a map of the transmission grid in the Chesapeake Bay Market for 1972.



CHESAPEAKE BAY
TRANSMISSION LINES IN THE
MARKET AREA
1972

FIGURE 13-7

Table 13.4

TRANSMISSION CIRCUIT LENGTH IN THE CHESAPEAKE BAY MARKET, 1972
(Figures are "circuit miles/circuit kilometers")

Utility	500 kV	230 Kv	138 Kv
Conowingo Pr Co.	24/39	2/3	2/3
Delmarva P&L Co.	4/5	23/38	229/370
Delmarva P&L of Md.	0/0	0/0	84/135
Susquehanna El	0/0	14/22	0/0
Chesapeake East	28/44	39/63	315/508
Baltimore G&E Co.	198/315	188/303	58/93
Potomac El Pr Co.	0/0	548/881	0/0
Chesapeake West	196/315	736/1184	58/93
Virginia E&P Co.	613/987	1060/1705	105/169
Chesapeake South	613/987	1060/1705	105/169
Chesapeake Market	837/1346	1835/2952	478/770

EXISTING PROBLEMS AND CONFLICTS

In addition to the conflicts of use which may arise in the Study Area as a result of multiple demands for water or land, the resolution of certain social issues currently affecting the utility industry could also influence use of water and land for the generation of electric power in the Study Area.

Prevailing controversies concerning the generation of electric power and its impact on the environment include such issues as esthetics, air pollution, water quality, impingement and entrainment of fish, radiological effects, and the disposal of nuclear wastes.

Steam generating plants are expansive installations that could present a relatively unsightly overall appearance and hydroelectric plants can often intrude on scenic areas. Both entail competitive use of water and may preclude other esthetic developments. Concealment of transmission towers and transmission lines is sometimes difficult; they cannot always be placed out of view or effectively blended into the surroundings.

The types and quantities of emissions from the combustion of fossil fuels in the production of electric power created a demand for air pollution control as a major siting criteria in planning future plants. The necessity for large quantities of cooling water introduces problems of fish impingement, entrapment, and entrainment. The effects of releasing this water in a heated condition and its impact on aquatic life are other issues of controversy. Environmental regulations currently prescribe the use of a closed cycle cooling system for generating units to be installed in 1985 and thereafter; however, the resulting reduction of heat input to the cooling water source may be offset by significant increases in evaporative water consumption. The varied impacts of the thermal and consumption effects may exchange an apparent current problem for a potential future problem.

During their operation nuclear power plants are permitted to release, under well controlled and carefully monitored conditions, low levels of radioactivity. Current technologies for the treatment and storage of radioactive wastes are characterized as currently adequate. The adequacy of these technologies however, are controversial in some quarters.

With increasing emphasis on environmental protection, the utility industry, in cooperation with the Federal Government, some state governments, and some research institutes, have ongoing programs attempting to minimize the environmental impact of electric power generation and still maintain a reasonable cost for electric power.

The public, government, and the electric industry in general are all currently enmeshed in a reassessment and reevaluation of the generation of electric power by nuclear fission. The public inquiry with regard to safety and long-term justification of a nuclear program and the economic impact of double-digit inflation on the cost of nuclear power has introduced some question regarding the future of nuclear power generation. Final resolution of these issues could influence the utilization of nuclear capacity throughout the country and in the Market Area. The Chesapeake Bay Market utilities presently plan the installation of considerable nuclear capacity but still anticipate substantial additions of fossil generation. Because of the lower thermal efficiencies of nuclear units, increasing nuclear capacity increases water use about 50 percent for each nuclear unit which replaces a comparably-sized fossil unit. Land use for plant siting is reduced because large fuel storage and handling areas, needed for coal or oil, are not required for nuclear fuel, but transmission rights-of-way could require more land because of the need to site nuclear facilities further from the population centers. Opportunities for joint use of the land would also tend to be less because of the remote locations, although such settings might be attractive for recreational development.

Should future events constrain the installation of additional nuclear capacity base load requirements would have to be met with generation by coal or oil. In this regard, conflicts between the national energy and environmental interests and between these interests and the economic vitality of the electric utilities are currently evident and resolution of these conflicts could have varied impacts on the water and land requirements.

The goal of national energy independence favors the consumption of coal while environemntal laws often preclude the combustion of certain types of coal in power plants without adequate environmental equipment. The resultant economic penalty, in addition to uncertainties of supply and regulatory postures pertaining to coal combustion, tends to discourage the use of coal. Coal-fired plants need relatively large land areas for coal storage, handling, and ash disposal. Fuel storage and handling and ash disposal in oil-fired plants involve less land area but would likely involve more waterfront land area to accomodate water borne oil transport. The use of imported oil would be undesirable from both energy independance and national security postures.

MANAGEMENT RESPONSIBILITIES

The electric utility industry is regulated at the Federal, state and local levels by agencies specifically established for this purpose. While virtually all aspects of utility business are under official scrutiny of one form or another, only those aspects related to water and land use are highlighted here.

The US Federal Power Commission, established in 1920 to administer the Federal Water Power Act, regulates the development of non-Federal hydroelectric resources. Specifically, the Commission reviews proposed non-Federal hydroelectric projects for inclusion in the overall development of water resources along a river reach, considering such matters as navigation, flood control, irrigation, recreation, and wildlife conservation. The Commission then issues a license stipulating requirements to be fulfilled in respect to the water resource utilization. The Federal Power Commission also gathers and compiles statistics on water resource matters, prepares water appraisal studies, and cooperates with other agencies in developing water management programs.

Other Federal agencies regulate utilities not as direct objects of jurisdiction but as entities influencing the use of land and water resources. The US Army Corps of

Engineers issues permits for constructing facilities in navigable waters, typically cooling water structures for steam-electric plants. The US Environmental Protection Agency promulgates air and water quality standards involving thermal and chemical discharges into water bodies and land use requirements for air and water pollution control equipment. Generating plant design and operations are influenced by these standards. The US Federal Energy Administration regulates the allocation of fuel oil and encourages the use of coal, thereby influencing the land area requirements which arise in consequence of burning each type of fuel. The US Nuclear Regulatory Commission controls the utilization of nuclear power, including the possible site location and cooling water releases to the water body serving the nuclear generating plants.

On the state and local level, agency responsibilities vary widely from state to state around the Bay, but a representative idea of such regulation can be obtained by citing the Brandon Shores #1 unit, a 600 Mw fossil unit scheduled by Baltimore G&E Co. for completion in 1978. The unit is to be located in Anne Arundel County, Maryland, just outside of Baltimore.

The State of Maryland Water Resources Administration must permit the use of Bay waters for cooling water purposes; the Department of Natural Resources and the Maryland Port Authority must pass on the construction activity along the shore front; the Highway Administration grants permission for transmission line routings over local highways. Anne Arundel County's Department of Inspections and Permits must approve the plant's sediment control programs; the Departments of Health and of Public Works must approve the treatment of sanitary products. Baltimore County and Baltimore City both have departments of planning and zoning which require approval of transmission line rights-of-way. In addition, Baltimore City's Bureau of Consumer Services must grant the permits for domestic water service.

THE MARYLAND POWER PLANT SITING PROGRAM

Recognizing the controversy surrounding efforts to increase the production of electric power, the state of Maryland

established a Power Plant Siting Program (PPSP) in 1971. The enabling legislation, which expires in 1985, was structured to insure that future demands for electric power would be met at reasonable cost, while simultaneously insuring that the natural environment would be protected.

The program is designed to predict the impact of existing and proposed generating units and to acquire alternative sites for utilities unable to find a suitable location for needed generation. In addition, numerous information gaps are being addressed in a long-range, stably-funded, and well-designed research program.

The Power Plant Siting Program, while providing for strict enforcement of environmental controls,imposes responsibility on the State to help utilities meet those standards.

CHAPTER III

FUTURE ELECTRIC POWER NEEDS

FUTURE DEMANDS

In light of the many variables normally affecting future electric power requirements and supply and the current uncertainties regarding fossil and nuclear fuels availability, environmental and energy goals, the possible conversion of certain end-use energy consumption to the use of electric power, load management, and the economic situation in general, the credibility of any long-term estimate of future power needs is considerably strained.

In current efforts to project electric power requirements some analysts opt for projections reflecting a quick return to historical trends while others argue for an extended or even permanent deviation from the past. Even among those who feel the growth rates will not return to historical values there is wide debate regarding the contemplated future growth rate pattern.

Since reasonable correlation between many of the factors of future electric power demand are undefined at this time, the projections developed here provide only a possible order of magnitude of the needs for electric power and the associated impact this need will impose on the resources of the Chesapeake Bay.

ASSUMPTIONS AND METHODOLOGY

In general, the projections of demand were developed by extrapolating various historical trends and subjectively modifying those trends to reflect judgements regarding factors currently in force and which could plausibly continue into the future. The estimated power requirements for the Chesapekae Bay Market were determined by combining the projected requirements for the three Sectors. These were derived by projecting compilations of historical data for the utilities encompassed by

each of the Sectors. These data were extracted from material on file with the Federal Power Commission.

Initially, two types of projections were developed for each Sector. One set involved multiple extensions of the historical trend developed for each Sector with various assumptions made regarding future growth rates. In this set three curves for each Sector were developed to reflect high, moderate, and low estimates of future energy requirements. A second set of projections was developed by extrapolating and subdividing estimated regional demands prepared in conjunction with the Water Resource Council (WRC) Second National Assessment. WRC estimates through the year 2000, for regional areas encompassing the Chesapeake Market Area, were extrapolated through the year 2020 and were subdivided in proportion to each Sector's historical relation to the total regional area. This second set of projections was used to help assess the reasonability of the curves obtained in the first set.

Both sets of data were plotted and analyzed with regard to general conformance with the newly emergent influences and a single set of projections was selected. The projections chosen reflect a belief that the general economic situation will improve in the near future and that growth in the use of electric power will continue but at a somewhat reduced rate. Persistent energy conservation policies will also result in a reduced rate of growth. This may be offset to some degree by the transition of some direct end-use consumptions of oil and natural gas to the use of electric power. Though no cohesive analysis is yet available to justify precise deviations from historical trends, a broad consensus does support a reduced growth rate. The magnitude of this reduction is currently the subject of concerned debate. For purposes of this Study the selected energy demands have been developed within a gradually reducing growth rate so that by the year 2020 the five year average compound annual rate of growth is approximately 4.5 percent. This is belived to be moderately conservative with regard to the potential for energy conservation but recognizes the significant role electric power will continue to play in the national economy.

Peak demands related to this selected energy projection were developed by applying the load factors for each Sector to the energy figures. The load factor for each Sector was determined by examining historical trends and assessing past and current behavior. Again, in recognition of the many prevailing uncertainties, no effort was made to project the load factor variation beyond 1980. After 1980 the load factors

were held at a constant level, based on prior trends. It is appreciated, though, that a more deliberative load management program could work to improve load factors.

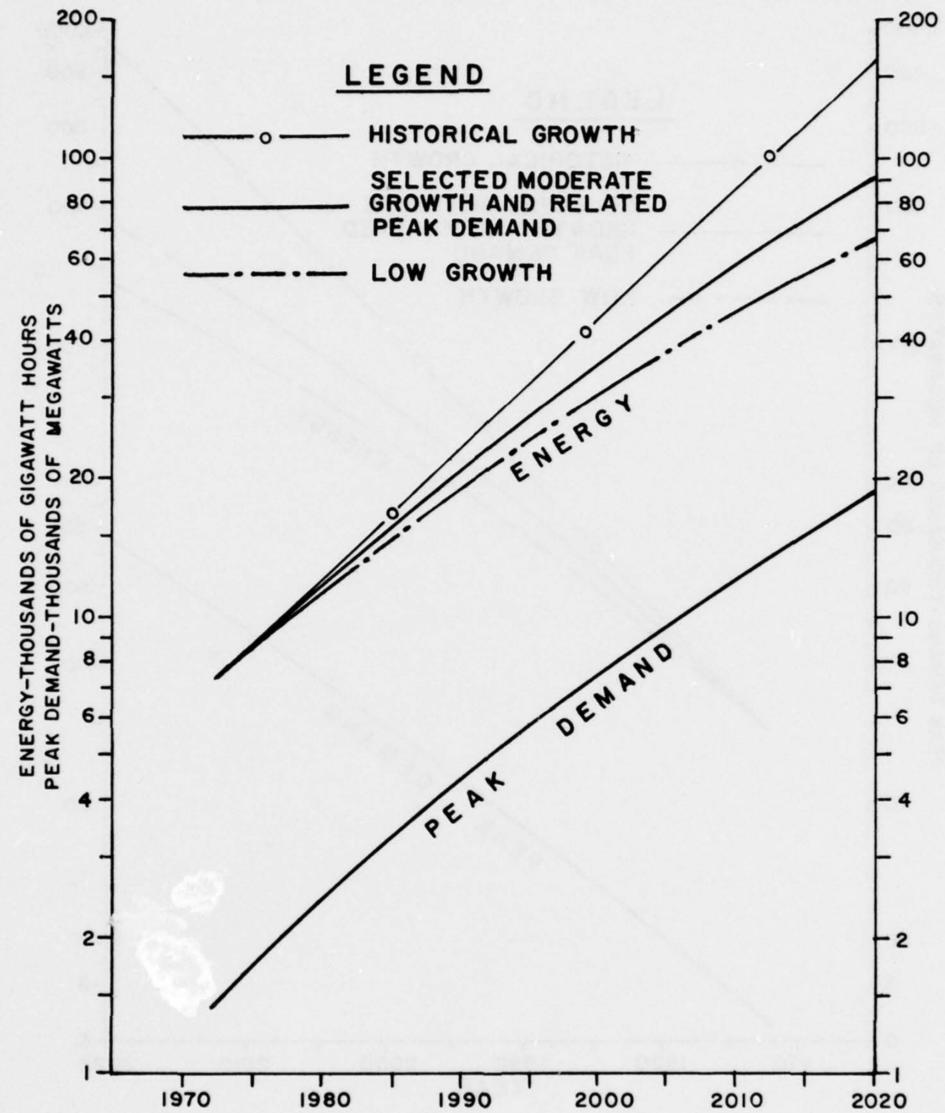
PROJECTED DEMANDS

Table 13-5 gives the resultant projections for each Sector and for the entire Chesapeake Market in five year steps from 1980 through 2020, together with the associated maximum demands and load factors. Three energy curves (historical, moderate, and low) and demands for the selected moderate energy growth are portrayed in Figures 13-8 thru 13-11. Where pumped storage power plants are contemplated, energy needed for pumping is added to the energy requirements. This energy is furnished during the periods of low demand and, therefore, does not act to increase the peak demand. The last column of Table 13-5 gives the total load of each Sector, including the pumping energy.

Table 13-5

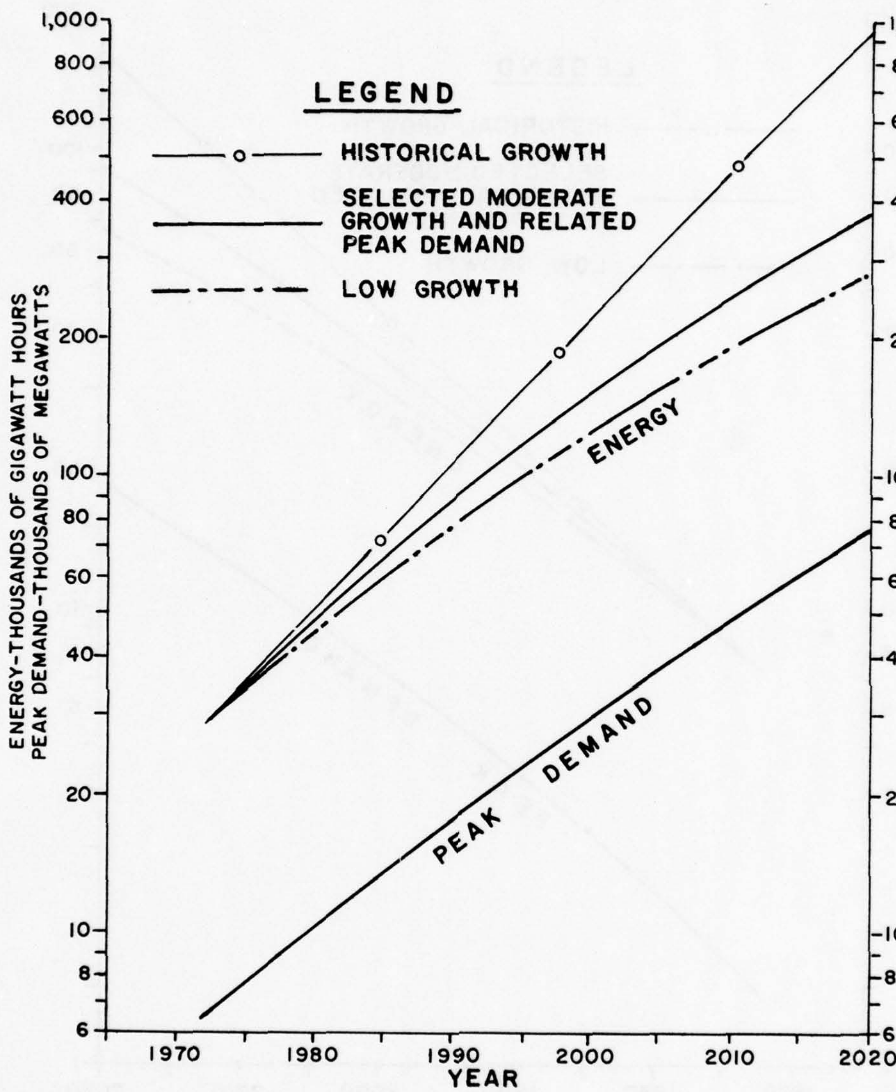
PROJECTED ENERGY REQUIREMENTS AND PEAK DEMAND
IN THE CHESAPEAKE BAY MARKET

Market Sector	Peak Demand MW	Energy Requirement GWh	Load Factor %	Pumping Energy GWh	Total Energy GWh
		1980			
East	2482	11990	55.0	-	11990
West	10008	48000	54.6	-	48000
South	10360	48360	53.0	-	48360
Total	22850	108350	53.9	-	108350
		1985			
East	3360	16045	54.5	-	16045
West	13490	65000	55.0	-	65000
South	13965	64855	53.0	4350	69205
Total	30815	145900	54.0	4350	150250
		1990			
East	4455	21270	54.5	-	21270
West	18160	87500	55.0	-	87500
South	18630	86500	53.0	4350	90850
Total	41245	195270	54.0	4350	199620
		1995			
East	5860	27975	54.5	-	27975
West	23870	115000	55.0	-	115000
South	24768	115000	53.0	4350	119350
Total	54498	257975	54.0	4350	262325
		2000			
East	7600	36390	54.5	-	36390
West	30840	149000	55.0	-	149000
South	32600	151500	53.0	7010	158510
Total	71040	336890	54.0	7010	343900
		2005			
East	9820	46885	54.5	-	46885
West	39435	190000	55.0	-	190000
South	42645	198000	53.0	7010	205010
Total	91900	434885	54.0	7010	441895
		2010			
East	12415	59270	54.5	-	59270
West	49815	240000	55.0	-	240000
South	55210	256330	53.0	7010	263340
Total	117440	555600	54.0	7010	562610
		2015			
East	15695	74930	54.5	-	74930
West	62265	300000	55.0	-	300000
South	70465	327155	53.0	7010	334165
Total	148425	702085	54.0	7010	709095
		2020			
East	19600	93825	54.5	-	93825
West	76590	370000	55.0	-	370000
South	88405	411625	53.0	7010	418635
Total	184595	875450	54.0	7010	882460



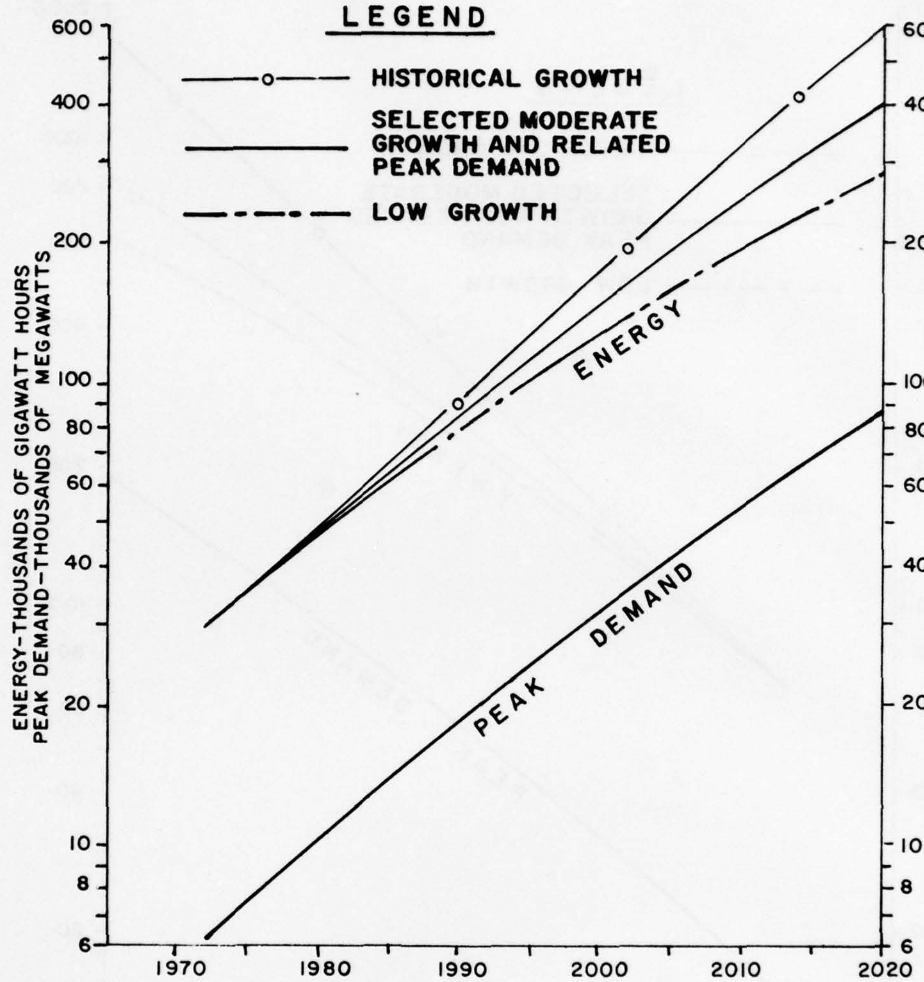
ENERGY AND PEAK DEMAND
IN
CHESAPEAKE EAST

FIGURE 13-8



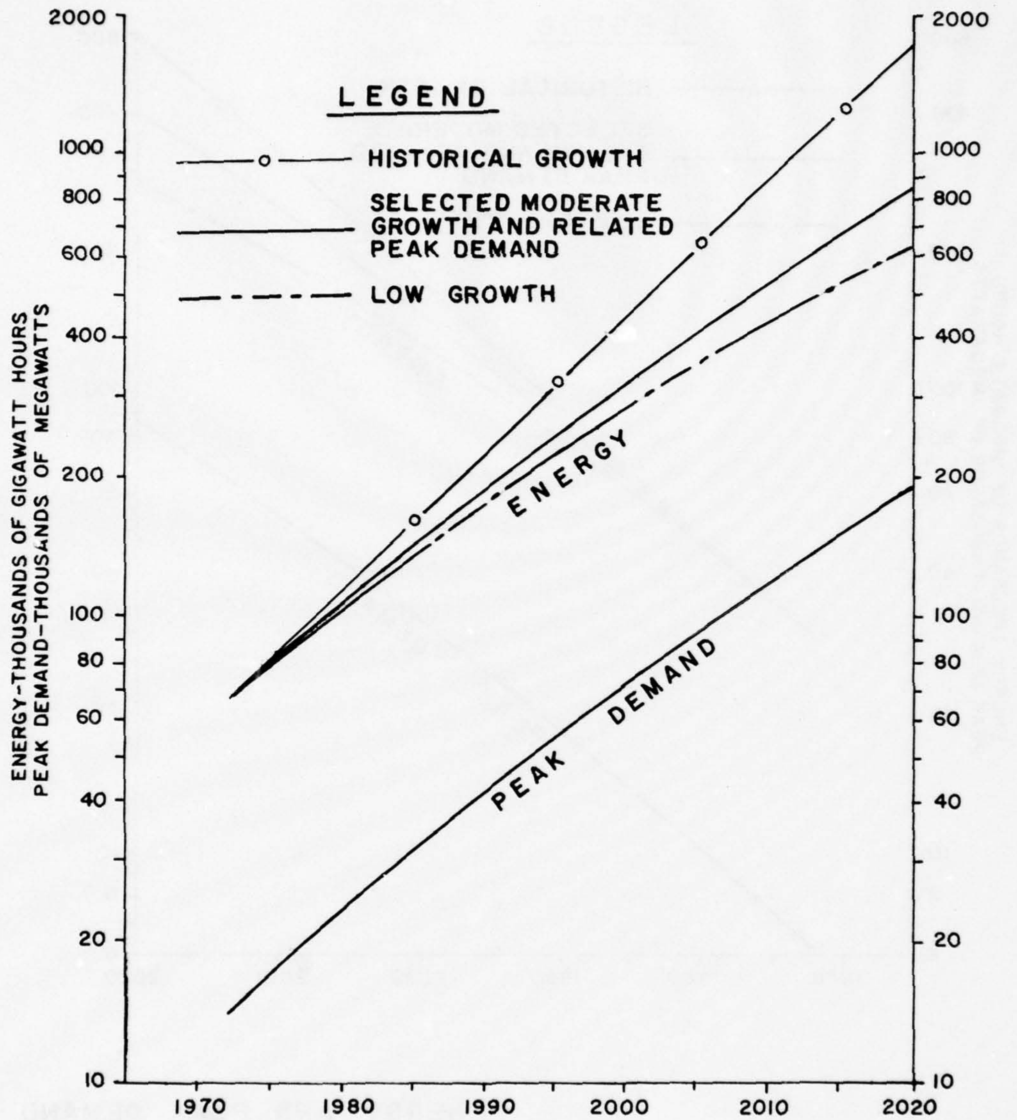
ENERGY AND PEAK DEMAND
IN
CHESAPEAKE WEST

FIGURE 13-9



ENERGY AND PEAK DEMAND
IN
CHESAPEAKE SOUTH

FIGURE 13-10



FUTURE ENERGY AND PEAK DEMAND
IN THE
CHESAPEAKE BAY MARKET

FIGURE 13-11

FUTURE SUPPLY

The development of current and new technologies and changing social policies will largely govern the installation of future generating plants. In the case of steam-electric capacity, the overwhelming bulk of Chesapeake Bay's Power supply, these developments and policies leading toward a plausible pattern of future electric power supply rest on fairly established and realistic axions.

ASSUMPTIONS AND METHODOLOCY

For this Study it was assumed that nuclear generation would be accepted by the public and that over the study period nuclear capacity would ultimately represent better than fifty percent of the installed capacity in the Market Area and would generate more than two-thirds of the energy. It was also assumed that domestic programs would provide sufficient fossil fuels to supplement the nuclear base-load generation.

The power supply facilities through 1985 are either in service, under construction or in the advanced design stage. Accordingly, the projected supply picture through this period reflects the generation already planned by utilities in the Market Area. This capacity includes shares of generating units located beyond boundaries of the Market Area and longtime contracts for the purchase of energy.

For the years after 1985 and through 2000 the supply program utilized current and expected trends of the relative proportions of steam generation to total generation, and of nuclear generation to fossil. Beyond the year 2000, capacity was projected to 2020 as an extrapolation of the trends with some modifications to reflect Market Area parameters. Capacity projected for meeting Market Area loads after 1985 was assumed to be sited within the Market Area to the degree that suitable sites were considered available.

As previously indicated, base-load generation is assumed to be increasingly provided by nuclear power with base-load coal or oil capacity moving into cycling or peaking operations. The "all other" category assumes installation of combustion type generation for peaking service in the near future with a possible introduction in the distant future of other generating modes not presently available. Existing hydroelectric capacity is kept in service throughout the study period. Although only the Bath County pumped storage project is presently scheduled for construction by Virginia E&P Co in Chesapeake South, provision for another 1000 megawatt project was made for the year 1995 to help balance out the load characteristics in the century to come.

The energy generated by each prime mover category was determined by the service for which each is assigned, with capacity factors declining from base-load service, thru cycling, to peaking.

Pumped storage plants are operated for peaking purposes and pumping requirements are considered to be 1.5 times the energy generated.

PROJECTED SUPPLIES

Table 13-6 shows the projected capacity making up the future power supply in the Chesapeake Bay Market and in each Sector for five year intervals from 1980 through 2020.

FUTURE NEEDS AND PROBLEM AREAS

The installation of electric power facilities as indicated in the preceding section will create demands on the resources of the Study Area. Generating plants and transmission

Table 13-6

PROJECTED POWER SUPPLY IN THE CHESAPEAKE BAY MARKET /1

Market Sector	Nuclear Steam Capb. MW	Nuclear Steam Gen. GWh	Fossil Steam Capb. MW	Fossil Steam Gen. GWh	Hydro & Pumped Storage Capb. MW	Hydro & Pumped Storage Gen. GWh	All-Other Capb. MW	All-Other Gen. GWh	Net Firm Receipt MW	Net Firm Receipt GWh	Total Supply MW	Total Supply GWh
1980												
East	321	2128	2152	9612	474	1719	288	250	(474)	(1719)	2761	11990
West	1765	9921	7898	35944	0	0	1744	1517	152	618	11559	48000
South	3506	21186	6361	24088	505	1118	530	468	300	1500	11202	48360
Total	5592	33235	16411	69644	979	2837	2562	2235	(22)	399	25522	108350
1985												
East	1631	10679	2095	5138	474	1719	288	228	(474)	(1719)	4014	16045
West	2865	16507	10498	46063	0	0	2294	1812	152	618	15809	65000
South	7100	38722	6834	24544	2345	3975	530	464	300	1500	17109	69205
Total	11596	65908	19427	75745	2819	5694	3112	2504	(22)	399	36932	150250
1990												
East	2941	15526	1882	5358	474	1719	488	386	(474)	(1719)	5311	21270
West	8165	43908	10539	41166	0	0	2294	1808	152	618	21150	87500
South	10078	55043	8524	29868	2345	3975	530	464	300	1500	21777	90850
Total	21184	114477	20945	76392	2819	5694	3312	2658	(22)	399	48238	199620
1995												
East	4251	21173	2289	6416	474	1719	488	386	(474)	(1719)	7028	27975
West	12665	68328	11713	43607	0	0	3094	2447	152	618	27624	115000
South	13838	75289	11059	37782	2345	3975	930	804	300	1500	28472	119350
Total	30754	164790	25061	87805	2819	5694	4512	3637	(22)	399	63124	262325
2000												
East	5561	27438	2926	8442	474	1719	688	509	(474)	(1719)	9175	36390
West	18365	98816	14644	47132	0	0	3094	2435	152	618	36255	149000
South	19478	105894	13594	44590	3470	5722	930	804	300	1500	37772	158510
Total	43404	232148	31164	100164	3944	7441	4712	3748	(22)	399	83202	343900

Table 13-6
(Cont'd)
PROJECTED POWER SUPPLY IN THE CHESAPEAKE BAY MARKET/1

Market Sector	Nuclear Steam Capb. MW	Nuclear Steam Gen. GWh	Fossil Steam Capb. MW	Fossil Steam Gen. GWh	Hydro & Pumped Storage Capb. MW	Hydro & Pumped Storage Gen. GWh	All-Other Capb. MW	All-Other Gen. GWh	Net Firm Receipt MW	Net Firm Receipt GWh	Total Supply MW	Total Supply GWh
2005												
East	6871	34561	4149	11815	474	1719	688	509	(474)	(1719)	11708	46885
West	24365	132833	17258	53615	0	0	3894	2934	152	618	45669	190000
South	26178	140714	18619	56270	3470	5722	930	804	300	1500	49497	205010
Total	57414	308108	40026	121700	3944	7441	5512	4247	(22)	399	106,874	441895
2010												
East	8191	42869	5235	15649	474	1719	888	752	(474)	(1719)	14314	59270
West	31865	170894	21258	64967	0	0	4694	3521	152	618	57969	240000
South	35558	184625	23734	70689	3470	5722	930	804	300	1500	63992	263340
Total	75614	398388	50227	151305	3944	7441	6512	5077	(22)	399	136275	562610
2015												
East	10811	54996	6435	19182	474	1719	888	752	(474)	(1719)	18134	74930
West	40865	216984	26258	78896	0	0	4694	3502	152	618	71969	300000
South	46278	234970	30494	90823	3470	5722	1330	1150	300	1500	81872	334165
Total	97954	506950	63187	188901	3944	7441	6912	5404	(22)	399	171975	709095
2020												
East	13811	68867	8058	24206	474	1719	888	752	(474)	(1719)	22757	93825
West	51365	271812	31258	93480	0	0	5494	4090	152	618	88269	370000
South	58338	295978	38944	114285	3470	5722	1330	1150	300	1500	102382	418635
Total	123514	636657	78260	231971	3944	7441	7712	5992	(22)	399	213408	882460

/1 Includes capacity and generation located beyond the Market boundaries.

lines on land resources while plant operations will place demands on the available water supply. Quantifying such demands on long-range bases is difficult because of the number and dynamic nature of the variables involved in long-range electric power development.

FUTURE POWER PLANT SITING AND COOLING METHODS

Reported schedules for future installations of generating capacity generally include the location, by city and state, of the new plants. Considering those plants presently under construction or in the advanced design stages, the locations of future Chesapeake facilities is fairly well known through 1985. For installations scheduled beyond 1985 uncertainty regarding specific sites often manifests itself in much capacity being carried as "undetermined".

For the Study, sites for plants in the Study Area were considered of paramount importance only for steam-electric plants, both fossil and nuclear, because of their demands for cooling water from the Bay's waterways. Such demands, in terms of withdrawals and consumption, are not made by "all other" plants and for these, therefore, siting is not examined in detail.

For capacity scheduled as "undetermined" in location and for that capacity projected beyond 1985 siting was postulated on the basis of several criteria. These, enumerated below, reflect the desire to have ample water supply, be near the load centers, keep transmission lengths short and be convenient to fuel transport systems. In addition, sites in Maryland were selected in accordance with criteria used in the Maryland Power Plant Siting Program. It should be noted however, that the sites as presented in this report are not necessarily those delineated in the Maryland Power Plant Siting Program.

a) Tributary headwaters were avoided since water flows generally cannot support significant amounts of capacity and these areas are often candiates for river recreation plans.

b) River reaches already included, or expected to be included, in the Wild and Scenic River system are avoided.

c) The main stems or lower reaches of large rivers and tributaries, or the coastal zone fronting the ocean, are favorable sites for new plants.

d) Fossil capacity is placed near or in the metropolitan areas of large cities but outside the central city itself.

e) Fossil capacity is placed in river reaches already supporting generating facilities, particularly groups of plants.

f) Nuclear capacity is placed well outside the metropolitan areas of large cities in conformity with Nuclear Regulatory Commission siting restrictions.

Because of the degree of uncertainty attending site location in the long-range future, no attempt was made to predict where the capacity beyond 2000 would be located. It must be noted of course, that only a reasonable and plausible scheme of future plant siting can be developed beyond the period of scheduled additions; sites which are projected cannot be construed to be a program for the placement of contemplated plants having a special sanction.

As one view of the generation pattern in the future Table 13.7 gives the sizes and locations of the steam-electric plants comprising the power supply for the year 2000. Figure 13-12 shows the geographic distribution of these plants, which can be compared with Figure 13.2 giving the power supply for the base year 1972.

The production of electricity by the steam cycle involves the condensation of exhaust steam back to water and the release of waste heat. All waste heat from steam-electric plants must eventually be discharged into the atmosphere. It may be transferred directly to the air or it may be transferred to water as an intermediate step and then to the air. Because of costs and engineering difficulties associated with direct transfer process, nearly all existing steam-electric plants use cooling water as an intermediate transfer agent. The process of moving the waste heat from the steam-generation cycle to the water is accomplished by heat transfer through a condenser. In this process cooling water is passed through the condenser tubing. The spent steam leaving the turbine is passed over the outside of the tubing and heat remaining in the steam is transferred through the tubing to

Table 13-7

STEAM ELECTRIC PLANTS LOCATED IN THE CHESAPEAKE BAY MARKET AREA 2000

Plant	Fuel	Service-Area	Location: City	Location: State	Capability MW
Chesapeake West					
Douglas Point	Nuclear	Potomac El Pr. Co.	Nanjemoy	MD	4600
Bush River*	Nuclear	Baltimore G&E Co.	Bush River	MD	4500
Chalk Point	Fossil	Potomac El Pr. Co.	Brandywine	MD	3418
Calvert Cliffs	Nuclear	Baltimore G&E Co.	Lusby	MD	3265
Elms*	Nuclear	Potomac El Pr. Co.	St. Marys City	MD	3000
Morgantown	Fossil	Potomac El Pr. Co.	Newburg	MD	2601
Brandon Shores	Fossil	Baltimore G&E Co.	Foremans Corner	MD	1200
Wagner	Fossil	Baltimore G&E Co.	Arundel Village	MD	774
Benning	Fossil	Potomac El Pr. Co.	Benning	DC	608
Potomac River	Fossil	Potomac El Pr. Co.	Alexandria	VA	499
Crane	Fossil	Baltimore G&E Co.	Baltimore	MD	400
					24865
Chesapeake East					
Bethlehem*	Nuclear	Delmarva P&L Md.	Bethlehem	MD	2620
Summit	Nuclear	Delmarva P&L Co.	Summit Bridge	DE	1540
Thornton*	Nuclear	Delmarva P&L Md.	Still Pond	MD	1310
Indian River	Fossil	Delmarva P&L Co.	Millsboro	DE	577
Edge Moor	Fossil	Delmarva P&L Co.	Edge Moor	DE	564
Vienna	Fossil	Delmarva P&L Md.	Vienna	MD	162
McKee Run	Fossil	Dover Municipal	Dover	DE	148
Delaware City	Fossil	Delmarva P&L Co.	Delaware City	DE	75
					6996
Chesapeake South					
North Anna	Nuclear	Virginia E&P Co.	Minerva	VA	3806
Free Ferry*	Nuclear	Virginia E&P Co.	Barco	NC	3760
Surry	Nuclear	Virginia E&P Co.	Surry	VA	3294
Roanoke*	Nuclear	Virginia E&P Co.	Palmyra	NC	2978
Yorktown	Fossil	Virginia E&P Co.	Yorktown	VA	2910
Chowan*	Nuclear	Virginia E&P Co.	Cofield	NC	2820
Ramirez*	Nuclear	Virginia E&P Co.	Mamie	NC	2820
Claremont*	Fossil	Virginia E&P Co.	Claremont	VA	2535
Possum Point	Fossil	Virginia E&P Co.	Dumfries	VA	2047
Smithfield*	Fossil	Virginia E&P Co.	Smithfield	VA	1690
Portsmouth	Fossil	Virginia E&P Co.	Chesapeake	VA	1495
Chesterfield	Fossil	Virginia E&P Co.	Chester	VA	1255
					31410
					63271

*Plant projected and sited by FPC; all others are existing or scheduled by the utilities.

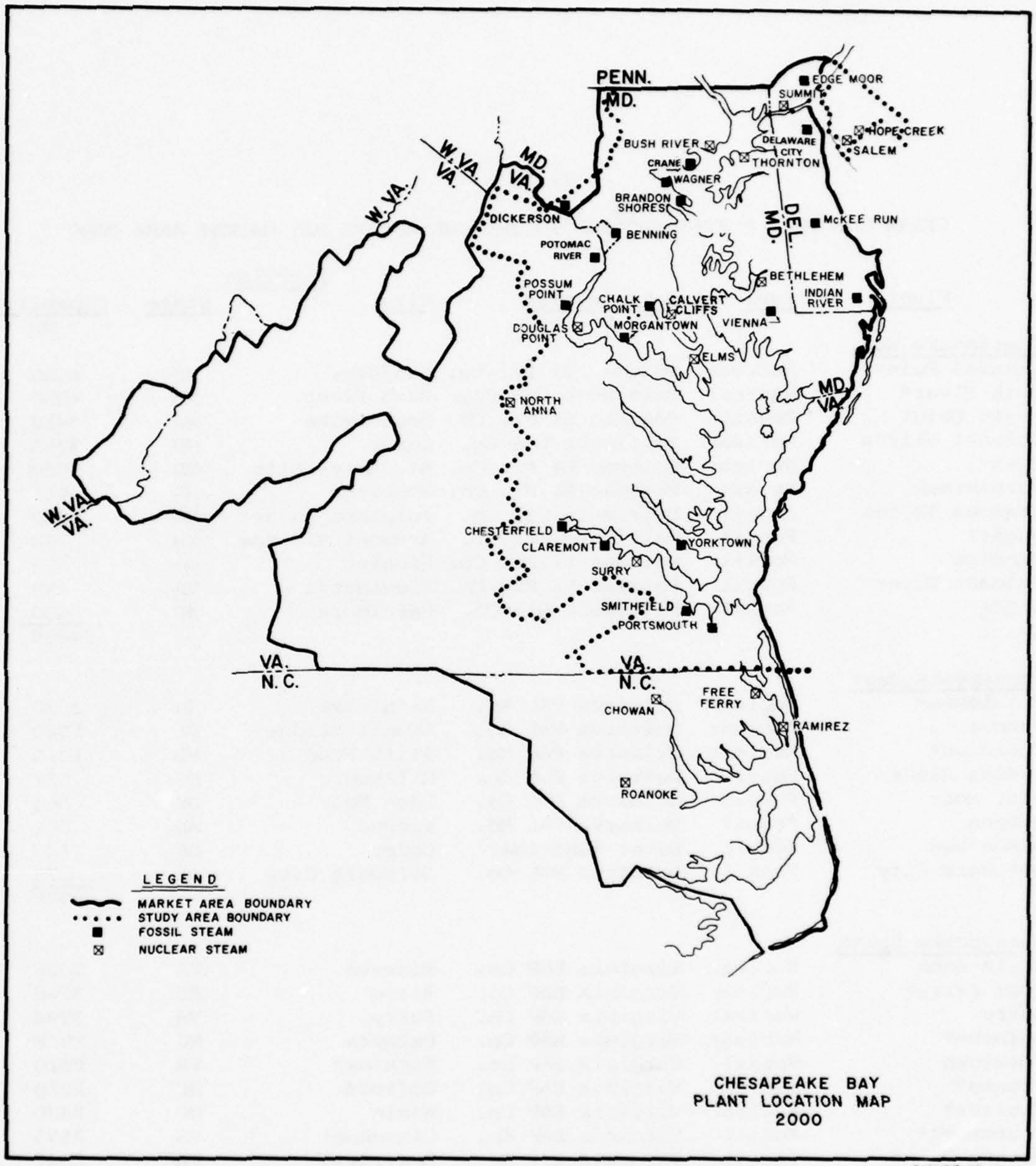

PENN.
MD.
W.VA.
VA.
MD.
VA.
W.VA.
W.VA.
VA.
DEL.
MD.
MD.
VA.
VA.
N.C.
VA.
N.C.
EDGE MOOR
SUMMIT
HOPE CREEK
SALEM
BUSH RIVER
DELAWARE CITY
THORNTON
CRANE
WAGNER
BRANDON SHORES
McKEE RUN
DICKERSON
BENNING
POTOMAC RIVER
BETHLEHEM
POSSUM POINT
CHALK POINT
CALVERT CLIFFS
INDIAN RIVER
DOUGLAS POINT
MORGANTOWN
VIENNA
ELMS
NORTH ANNA
CHESTERFIELD
CLAREMONT
YORKTOWN
SURRY
SMITHFIELD
PORTSMOUTH
FREE FERRY
CHOWAN
RAMIREZ
ROANOKE
LEGEND
MARKET AREA BOUNDARY
STUDY AREA BOUNDARY
FOSSIL STEAM
NUCLEAR STEAM
CHESAPEAKE BAY
PLANT LOCATION MAP
2000

FIGURE 13-12

the cooling water which in turn carries it away. The heated cooling water, having accomplished its task, is returned to its source.

All but three of the present steam plants in the Chesapeake Market employ "once-through" cooling, in which the condenser cooling water flow is drawn from and discharged to a natural body of water. The rate of flow of the cooling water over the condenser coils and the rise in cooling water temperature due to the heat removal process differ among plants in relation to the various design and operating conditions. There is a slight consumptive use of water in the once-through system due to the small evaporative loss caused by the increased temperature of the condenser cooling water discharge.

Withdrawals of water for cooling at steam-electric plants currently constitute the largest industrial diversion of water. In the Chesapeake Market either fresh or saline water is used for this purpose, depending on the location of each individual plant. The amount of water required depends upon the type of plant, its efficiency, and the temperature rise of cooling water in the condenser, usually in the range of $10^{\circ}F$ to $25^{\circ}F$ ($6^{\circ}C$ to $14^{\circ}C$). Currently, a large nuclear steam-electric plant requires approximately 50 percent more condenser water for a given temperature rise than a fossil plant of equal size. The higher requirements result from lower turbine inlet steam temperatures and lower operating efficiencies of nuclear plants.

Where adequate supplies of natural water are available the once-through cooling system is usually adopted because it is the most economical method of cooling.

Where natural bodies of water of adequate size are not available at the site, or are excluded from use by water quality standards, cooling ponds may be constructed to provide the cooling water source. In this case, water would be recirculated between the condenser and the man-made pond. Sufficient supplemental inflow into the pond would be needed to replace both the normal evaporation and that induced by the addition of the waste heat from the plant. The only cooling pond installation contemplated for the Chesapeake Study Area is that at the North Anna plant, presently under construction.

Where cooling towers are used the heated condenser water is cooled for reuse by a stream of flowing air. The air flow is usually that of a natural draft rising through the tower, which is hyperbolically contoured to create the necessary

barometric head. Such natural draft towers are huge affairs, some 300 feet (100 meters) in diameter at the base and some 450 feet (150 meters) tall. Each tower provides cooling for a generating plant of about 500 to 1000 megawatts.

In the wet cooling tower, the warm water is sprayed into the stream of flowing air. This facilitates the heat dissipation by evaporation as air moves through the tower. The cooled water is collected in a basin under the tower from which it can be pumped back to the condenser for reuse. The evaporated water is made up by withdrawals from a local natural water body.

While the Chalk Point #3 unit is the only natural draft wet tower currently in use in the Study Area, many are included in the plans of scheduled units going into service over the next ten years. In the Study Area a few small units have wet towers whose air flow is driven by mechanical fans, but no additional facilities of this type are anticipated.

In a dry cooling tower the heated water from the condenser is confined in piping within the tower while an air stream forced over it carries off the heat. Since the heat dissipation is entirely by convection and conduction there are no evaporative losses of water with consequent makeup requirements. Because of the large surface area required for heat transfer and the large volumes of air that must be circulated, dry cooling towers are substantially more expensive than the wet towers. Overall operating efficiency in steam-electric plants is somewhat decreased due to the larger energy requirement of dry cooling processes as compared to the wet, or evaporative, cooling processes. In addition, the technology of large scale dry cooling towers is not yet generally considered to be commercially acceptable. No dry towers are now used or scheduled anywhere in the Study Area.

Under the present EPA regulations, once-through cooling is prohibited on all plants scheduled for service in 1985 and thereafter. Plants scheduled before 1985 employing the once-through system may retain them throughout the remainder of their useful lives. For this Study it is assumed that all projected capacity will employ wet towers rather than dry towers or ponds.

COOLING WATER FACTORS

For a given rate of heat removal, the temperature rise in the cooling water is inversely proportional to the amount of water circulated through the condenser. The size of the condenser and the amount of water circulated can be varied substantially.

By varying the efficiencies, cooling temperature rise, fuel type, plant load-carrying function, and cooling system design, a set of water requirements for steam plant cooling purpose can be developed. These requirements are shown in the upper half of Table 13.8 for a 1,000 megawatt plant operating continuously at full capability for each design of plant and cooling facility. The use factors decline gradually in future years to reflect the anticipated modest increases in thermal efficiencies arising from continued design improvements.

CONSUMPTIVE USE FACTORS

As stated previously, the heat added to the water as it flows through the condenser may be dissipated to the atmosphere in several ways. For the once-through system, the amount of water eventually consumed by evaporation from the receiving water body averages less than 1% of the condenser cooling water flow. For the cooling pond, whose temperature rise is somewhat greater than for once through systems, the evaporative loss is about 1% of the condenser flow. The loss is greatest in the cooling tower-a little over 2%.

The loss factors, expressed as millions of gallons per day for each 1,000 megawatt plant operating 24 hours per day, are presented in the lower half of Table 13.8. Again, the decline in future years reflects continuing improvements in plant efficiencies.

WATER USE IN THE STUDY AREA

With a plausible scheme of future plant sites, each accomodating an assigned plant and cooling facility type, an estimated water use can be determined to quantify the water demands on the Chesapeake Bay Study Area.

To illustrate the magnitude of heat discharged to the cooling after body by existing generating plants, Table 13-9 assembles thermal data for 1972 on plants within the Chesapeake Bay Market.

Table 13-8

CONDENSER FLOW AND EVAPORATIVE LOSS FACTORS*
FOR STEAM-ELECTRIC PLANTS IN THE CHESAPEAKE BAY MARKET
(Millions of gallons per day; millions of cubic meters per day)

	Once Through	Cooling Pond	Wet Towers
Temperate Rise Across Condenser - °F;°C	13;7	18;10	24;13
Condenser Flow			
For 1980			
Nuclear	1,450;5.49	1,047;3.96	785;2.97
Fossil Base	899;3.40	649;2.46	487;1.84
Fossil Cycling	1,227;4.64	886;3.35	665;2.52
For 1985 thru 1995			
Nuclear	1,408;5.33	1,017;3.85	763;2.89
Fossil Base	880;3.33	635;2.40	477;1.81
Fossil Cycling	1,161;4.39	839;3.18	629;2.38
For 2000 thru 2020			
Nuclear	1,240;4.69	896;3.39	672;2.54
Fossil Base	767;2.90	554;2.10	416;1.57
Fossil Cycling	1,105;4.18	798;3.02	599;2.27
Evaporative Loss			
For 1980			
Nuclear	9;0.03	12;0.05	18;0.07
Fossil Base	6;0.02	7;0.03	11;0.04
Fossil Cycling	8;0.03	10;0.04	15;0.06
For 1985 thru 1995			
Nuclear	9;0.03	11;0.04	17;0.06
Fossil Base	5;0.02	7;0.03	11;0.04
Fossil Cycling	7;0.03	9;0.03	14;0.05
For 2000 thru 2020			
Nuclear	8;0.03	10;0.04	15;0.06
Fossil Base	5;0.02	6;0.02	9;0.03
Fossil Cycling	7;0.03	9;0.03	14;0.05

Factors are for a 1,000 megawatt plant operating 24 hours per day at full capability or are for each 24 gigawatthours of generation.

*Factors taken from Water Resources Council Second National Assessment. Recent revisions reflect higher heat rates and somewhat higher water use.

Table 13.9

COOLING WATER USE AND ILLUSTRATIVE HEAT IMPACT BY STEAM-ELECTRIC PLANT IN THE CHESAPEAKE BAY MARKET - 1972

			REPORTED /6				CALCULATED		
Plant	Water Source	State	Capacity (MW)	Plant Generation (GWh)	Average Cooling Water Discharge (ft^3/Sec)	Maximum Cooling Water Temp. Rise (°F)	Average Cooling Water Temp. Rise (°F)	Total Annual Heat Discharge (GWh)	Design Operating Ratio /1 (Disch./Gen.)
Chesterfield	James Rv.	Va.	1484	8145	1408	34	14	11647	1.43
Morgantown	Potomac Rv.	Md.	1251	6900	2070	9	7	8211	1.19
Wagner	Patapsco Rv.	Md.	1043	3731	1006	15	8	4776	1.28
Portsmouth	Elizabeth Rv.	Va.	650	3156	795	17	9	3945	1.25
Dickerson	Potomac Rv.	Md.	587	3626	608	16	12	5142	1.14
Potomac River	Potomac Rv.	Va.	499	2511	697	15	8	3239	1.29
Possum Point	Potomac Rv.	Va.	491	2942	465	19	16	4384	1.49
Yorktown	York Rv.	Va.	375	2200	445	19	10	2574	1.17
Riverside	Patapsco Rv.	Md.	334	1344	486	15	8	2283	1.70
Crane	Seneca Cr.	Md.	400	2136	636	13	7	2755	1.29
Indian River	Indian Rv.	De.	340	2160	614	14	9	3110	1.44
Westport	Patapsco Rv.	Md.	194	651	353	17	7	1374	2.11
Edge Moor	Delaware Rv.	De.	390	2175	630	18	8	2784	1.28
Benning /2	Anacostia Rv.	D.C.	748	2151	233	15	8	1076	0.50
Bremo	James Rv.	Va.	254	754	152	NR	12	1071	1.42
Chalk Point	Patuxent Rv.	Md.	728	3403	697	15	9	3777	1.11
Gould Street	Patapsco Rv.	Md.	174	674	237	20	9	1267	1.88
Twelfth Street	Kanawha Canal	Va.	103	65	296	9	1	127	1.95
Vienna /2	Nanticoke Rv.	Md.	257	815	216	10	6	750	0.92
Buzzard Point	Anacostia Rv.	D.C.	270	492	238	9	8	1058	2.15
Delaware City	Delaware Rv.	De.	130	849/5	150	NR	10	866	1.02
Reeves Avenue	Elizabeth Rv.	Va.	100	187	100	15	2	127	0.68
McKee Run /3	City Water Supply	De.	38	155	-	-	-	-	-
Surry /4	James Rv.	Va.	848	370	-	-	-	-	-

/1 Calculated from design temperature rise across condenser and design condenser flow at full load 100 percent plant factor generation for units using once-through cooling.
/2 Partially cooling tower (s).
/3 All cooling Tower (s).
/4 Water use data not reported; Surry placed in service in late December, 1972.
/5 368 GWh of this generation was for industrial use.
/6 Data is based on information reported in FPC Forms 12 & 67.
All plants are once-through cooling, except as noted.

The heat discharge is calculated from the design operating ratio and actual annual generation and is stated in gigawatthours for ready comparison with the annual generation. The ratio of discharge to generation gives a visualization of the reject heat relationship to full load generation. The average cooling water temperature rise is calculated from the actual average cooling water discharge and the calculated heat discharge. Figure 13-12 shows that the generation of the Market Area is expected to be concentrated in the shore areas within the Study Area. For the plants so located in the Study Area, Table 13-10 and Table 13-11 give the withdrawal and consumption by five year intervals from 1980 through 2000. The amounts shown account for new units added and old units removed throughout the period, with regard to the type of fuel and cooling system.

From 2000 through 2020, when plant siting cannot be projected with any degree of confidence, Table 13.12 presents the water use based on each Sector's total fossil and nuclear capacity. The use factors employed were those for the year 2000. Technological improvements may reduce the water requirements for steam-electric generation by increasing the thermal efficiencies of the energy conversion process.

The amount of water required for cooling and for consumptive use figured largely in the placement of capacity at specific sites, particularly in the fresh water reaches of the Study Area. Through the year 2000, the annual average flows in each river, obtained from the USGS Water Supply Papers, were used. The withdrawal and consumptive uses of a plant at a prospective site were compared to the natural river flow at that site. Where the river flow could not support the plant's consumptive demand, the site was relocated.

LAND USE BY POWER FACILITIES

Evaluation of electric utility land use in the Chesapeake Bay Study Area was restricted to that required for large steam

Table 13-10

ESTIMATED WATER WITHDRAWALS IN THE CHESAPEAKE BAY STUDY AREA, 1980-2000
(Millions of gallons per day)**

Plant Name	Water Source	1980	1985	1990	1995	2000
Chesapeake East						
Salem	Lower Alloways Creek	1,106	2,205	2,205	2,205	1,859
Edge Moor	Delaware River	287	274	174	174	156
Indian River	Indian River	237	211	211	211	127
Vienna	Nanticoke River	117	94	94	94	64
Bethlehem	Choptank River	-	-	24	48	40
Hope Creek	Lower Alloways Creek	-	40	40	40	33
Delaware City	Delaware River	59	61	61	35	30
Summit	Chesapeake & Delaware Canal	-	28	28	28	24
Thornton	Sassafras River	-	-	-	-	20
McKee Run	City Wells	1	1	1	1	1
Sector Total		1,807	2,914	2,838	2,836	2,354
Chesapeake West						
Calvert Cliffs	Chesapeake Bay	1,790	1,765	1,765	1,792	1,511
Morgantown	Potomac River	569	717	717	717	621
Chalk Point	Patuxent River	337	348	348	350	300
Dickerson	Potomac River	267*	284*	291*	291*	244*
Potomac River	Potomac River	227*	235*	235*	235*	198*
Wagner	Patapsco River	341	307	307	307	171
Crane	Seneca Creek	182	188	188	188	159
Douglas Point	Potomac River	-	20	62	62	70
Bush River	Chesapeake Bay	-	-	27	54	69
Elms	Chesapeake Bay	-	-	-	-	46
Benning	Anacostia River	79*	81*	16*	16*	8*
Brandon Shores	Patapsco River	-	5	5	5	5
Riverside	Patapsco River	152	157	72	-	-
Gould Street	Patapsco River	79	82	49	-	-
Buzzard Point	Anacostia River	123*	127*	-	-	-
Westport	Patapsco River	88	91	-	-	-
Sector Total		4,234	4,407	4,082	4,017	3,402
Chesapeake South						
Surry	James River	1,599	1,607	1,607	1,608	1,353
Possum Point	Potomac River	612	619	619	619	538
Yorktown	York River	555	574	581	589	496
Chesterfield	James River	676*	576*	576*	576*	486*
Portsmouth	Elizabeth River	296	306	311	311	262
North Anna	North Anna River	36*	69*	69*	69*	58*
Claremont	James River	-	-	-	-	18
Smithfield	James River	-	-	-	15	12
Sector Total		3,774	3,751	3,763	3,787	3,223
Study Area Total		9,815	11,072	10,683	10,640	8,979

*Plant located on fresh water reaches of river.
**For million cubic meters per day multiply all figures by 0.003785

Table 13-11

ESTIMATED WATER CONSUMPTION IN THE CHESAPEAKE BAY STUDY AREA, 1980-2000
(Millions of gallons per day)**

Plant Name	Water Source	1980	1985	1990	1995	2000
Chesapeake East						
Bethlehem	Choptank River	-	-	16	32	27
Hope Creek	Lower Alloways Creek	-	27	27	27	22
Summit	Chesapeake & Delaware Canal	-	19	19	19	16
Thornton	Sassafras River	-	-	-	-	13
Salem	Lower Alloways Creek	7	14	14	14	12
Indian River	Indian River	2	1	1	1	1
Edge Moor	Delaware River	2	2	1	1	1
Vienna	Nanticoke River	1	1	1	1	/1
McKee Run	City Wells	1	1	1	1	/1
Delaware City	Delaware River	/1	/1	/1	/1	/1
Sector Total		13	65	80	96	92
Chesapeake West						
Douglas Point	Potomac River	-	13	41	41	47
Bush River	Chesapeake Bay	-	-	18	36	46
Elms	Chesapeake Bay	-	-	-	-	31
Calvert Cliffs	Chesapeake Bay	11	11	11	29	25
Dickerson	Potomac River	2*	7*	11*	11*	10*
Chalk Point	Patuxent River	6	5	5	7	9
Morgantown	Potomac River	4	4	4	4	6
Brandon Shores	Patapsco River	-	3	3	3	3
Benning	Anacostia River	2*	2*	2*	2*	2*
Wagner	Patapsco River	2	2	2	2	1
Potomac River	Potomac River	1*	1*	1*	1*	1*
Crane	Seneca Creek	1	1	1	1	1
Riverside	Patapsco River	1	1	/1	-	-
Gould Street	Patapsco River	1	/1	/1	-	-
Buzzard Point	Anacostia River	1*	1*	-	-	-
Westport	Patapsco River	1	1	-	-	-
Sector Total		33	52	99	137	182
Chesapeake South						
North Anna	North Anna River	24	46	46	46	39
Surry	James River	10	31	31	31	26
Claremont	James River	-	-	-	-	12
Yorktown	York River	4	3	8	13	11
Smithfield	James River	-	-	-	10	8
Possum Point	Potomac River	4	8	8	8	7
Portsmouth	Elizabeth River	2	2	5	5	5
Chesterfield	James River	4*	3*	3*	3*	3*
Sector Total		48	93	101	116	111
Study Area Total		94	210	280	349	385

* Plant located on fresh water reaches of river.
** For million cubic meters per day multiply all figures by 0.003785.
/1 Less than one.

Table 13-12

ESTIMATED WATER REQUIREMENTS FOR PROJECTED INSTALLED CAPACITY IN THE CHESAPEAKE BAY STUDY AREA, 2005-2020

	PROJECTED INSTALLED CAPACITY (Megawatts)			WATER REQUIREMENTS (MGD;MCD)*	
Sector	Nuclear	Fossil	Total	Withdrawal	Consumption
			2005		
East	11342	4149	15491	2335; 8.85	123; 0.47
West	18365	13317	31682	2569; 9.72	238; 0.90
South	9300	15997	25297	861; 3.26	167; 0.63
Total	39007	33463	72470	5765;21.83	528; 2.00
			2010		
East	12662	3935	16597	2204; 8.35	137; 0.52
West	21985	14687	36672	1387; 5.26	287; 1.09
South	11176	21172	32348	926; 3.51	210; 0.79
Total	45823	39794	85617	4517;17.12	634; 2.40
			2015		
East	12905	4335	17240	1151; 4.36	146; 0.55
West	27100	15857	42957	741; 2.81	349; 1.32
South	12892	24818	37710	645; 2.44	246; 0.93
Total	52897	45010	97907	2537; 9.61	741; 2.80
			2020		
East	12360	5158	17518	225; 0.85	150; 0.57
West	32000	18357	50357	619; 2.35	412; 1.56
South	14832	29486	44318	435; 1.65	290; 1.10
Total	59192	53001	112193	1279; 4.85	852; 3.23

*MGD = million gallons per day
MCD = million cubic meters per day

electric plants and the related high-voltage transmission rights-of-way. No attempt was made to estimate land use requirements associated with subtransmission or distribution facilities. Determination of future demands for land related to generation and transmission is complicated by the lack of standardized requirements. Each installation of plant or line is unique, requiring land as a function of a specific site or line location. Power plant land requirements vary with regard to plant type, size, location, fuel use, and exclusion factors. They meet the need for turbines; generators; boilers or reactors; fuel handling and storage; waste handling and disposal; chemical treatment, cooling, and pollution control equipment; substation, switch yard and other facilities. Additionally, sites also often include room for future expansion, recreational areas, buffer zones and auxiliary operations.

Transmission lines require land for structures (poles, tower, etc.) and electrical clearances of the conductors. Occasionally, nonutility use is made of the ground beneath the lines, but in such applications only the land required for the utility corridor is considered part of the utility demand on the Bay's land resources.

Estimates of the land required for typical 3000 MW steam-electric plants installed in rural areas are shown below.

Plant Fuel	Approximate Area	Remarks
Coal	900 to 1200 acres 3.6 to 4.8 Km^2	Assumes onsite coal storage and ash disposal.
Nuclear	200 to 400 acres 0.8 to 1.6 Km^2	Assumes buffer zone and expansion space.
Gas	100 to 200 acres 0.4 to 0.8 Km^2	Assumes pipeline delivery and modest onsite fuel storage tanks.
Oil	150 to 350 acres 0.6 to 1.4 Km^2	Assumes adequate onsite fuel storage.

The figures reflect a national picture and therefore were only used as a guide in the preparation of data used to depict requirements in the Study Area. For the purposes of the Chesapeake Study reported data on the plants existing in the area was compiled.

GENERATING PLANT LAND USE

Because there is virtually no change in the hydroelectric capacity over the time span of this study, no hydro land use projections are included. This was also true for the "all-other" plants, presently gas turbine and Diesel plants, which require little area and would have only relatively small demand for land. The steam-electric plant, being larger and more restrictively placed near water bodies, constitues the primary land user for generating plants.

By dividing the sum of all the reported land areas for steam-electric plants in the Study Area by the sum of the associated capacities a gross average land use of about 0.5 acre (2000 square meters) per megawatt of capacity was developed. This figure is based on face-value acceptance of the available individual plant data. Existing land areas by plant in the Study Area range from 6 acres (24,000 square meters) at Gould Street to 1160 acres (4.7 square kilometer) at Chalk Point. On a per megawatt basis plant areas range from 1.59 acre ($6400 m^2$) at Chalk Point to 0.03 acre ($138\ m^2$) at Gould Street.

Assuming that no substantial advances are made in reducing the bulk occupied by facilities attendant to steam-electric generation, an indication of a possible land demand may be obtained by applying the use factor above to the installed capacity scheduled for future years. Demands developed in this manner are shown in Table 13.13 for the steam-electric plants located within the Study Area. From 1980 through 2000, the sites came from the plant siting material developed earlier in this Chapter. For the years 2010 and 2020, for which no specific siting was compiled, the area use inside the Study Areas was approximated by assuming that the plant capacity ratio of the Study Area to the Market Area for 2000 was the same thereafter. By way of comparison, the land area of Washington (DC,) is about 42,900 acres or 174 square kilometers.

TRANSMISSION LINE LAND USE

Land requirements were estimated by considering the typical, single circuit support structures and conductor configurations. These needs, expressed as area per linear length of line, are given below.

ORDER OF LAND USE FOR TRANSMISSION LINES
(typical single cirucuit construction)

voltage	138 kv	230 kv	500 kv	765 kv
acre/mile	13	15	24	27
m^2/Km	32,500	37,500	60,000	67,500

Voltage levels above 765 kilovolt are presently under active investigation for possible future use for overlaying the existing 500 and 765 kilovolts grids in various parts of the country. Prospective levels of 1100, 1300, and 1500 kilovolts are being considered. Because the electrical properties of free air under such high tensions are still being studied, clearances and associated land usage cannot be reliably stated, but for this study 30 to 35 acre/mile or 75,000 to 90,000 square meters/kilometer seems to be plausible.

Unlike generation, whose increase over the years matches the load growth, transmission line length is difficult to predict beyond the period of announced scheduled construction of new lines. The utilities report to the Federal Power Commission broad-brush "conceptual" transmission schemes for a ten-year period beyond the scheduled construction program. From these, a general pattern of transmission line expansion can be gleaned and used as a specimen of what the future demand for land area may be. Since the conceptual plans treat only the highest voltages, 500 kilovolt and above, the 230 and 138 kilovolt systems are assumed to equal the length of the 500 kilovolt grid, for the sake of obtaining at least an order of land use.

Base on estimated lengths of line in the existing 1972, scheduled 1982, and conceptual 1992 transmission grids in the three Sectors of the Chesapeake Bay Market, table 13.14 gives the associated land requirements. It is reasonable to assume that the bulk of future transmission would lie in the Bay Study Area, based on the location of the principal load centers and generating plants. As noted earlier Washington (DC) occupies about 174 square kilometers or 42,900 acres.

A potentially complicating factor in transmission growth is the placement of new facilities underground, where the land use is reduced considerably. At present, underground transmission exists only in the very large urban areas. Rural and suburban construction is entirely overhead. The increasing density of load in the cities will no doubt lead to more underground lines at higher voltages, but the lengths are likely to be relatively short extending only to the outskirts of the urban areas where

Table 13-13

ORDER OF LAND USE FOR STEAM-ELECTRIC PLANTS IN THE CHESAPEAKE BAY STUDY AREA
(Thousands of acres; square kilometers)

Sector	1980	1985	1990	1995	2000	2010	2020
East	1.5; 6.0	3.3; 12.2	3.9; 15.6	6.5; 26.0	8.4; 33.6	13.6; 53.2	21.8; 86.9
West	4.8;19.3	6.7; 26.7	9.4; 37.4	12.2; 48.8	16.5; 66.0	26.6;106.2	41.3·165.2
South	4.1;16.4	6.1; 24.5	6.6; 26.5	7.9; 31.6	9.2; 36.7	16.3; 65.2	26.7;107.0
Total	10.4;41.7	16.1; 63.4	19.9; 79.5	26.6;106.4	34.1;136.3	56.5;224.6	89.8;359.1

Table 13.14

EXISTING AND PROJECTED LAND USE BY TRANSMISSION LINES
IN THE CHESAPEAKE BAY MARKET
(Thousand acres; Square kilometers)

Sector	1972	1982	1992
East	5.3; 21.5	12.0; 48.6	14.5; 58.7
West	32.0;128.6	54.3;218.6	115.9;461.5
South	16.5; 66.3	24.4; 98.0	31.0;124.3
Total	53.8;216.4	90.7;364.9	161.4;644.5

it would join the overhead transmission. Thus, it is assumed that throughout the study period, all area outside the present metropolitan domains will permit overhead construction.

SENSITIVITY ANALYSIS

The future utility industry use of Chesapeake Bay water and land resources is dependent on the number and size of the generation and transmission facilities that will be required by the utility industry to insure an adequate and reliable power supply to satisfy the projected load growth.

The water and land use pattern presented is based on a moderate growth, neither overly optimistic nor overly pessimistic. It also assumes that between now and the year 2020, no significant contribution to electric power generation would come from other than present day technological knowledge, apart from modest improvements in thermal efficiencies. Hence, land and water use would be approximately proportional to the energy requirements under the three cases--low, moderate, and historical--of load growth examined for this Study.

Table 13-15 presents land and water use sensitivity to the growth of electric power as projected in each sector for the year 2000 and 2020. For the moderate load-growth case, withdrawal requirements in the Chesapeake Bay Study Area would decrease over the period 2000 to 2020 from 8,979 million gallons per day to 1,279 (33.99 million cubic meters per day to 4.84), due to the gradual replacement of older once-thru generating units by cooling-tower units. Also resulting from this replacement is the increase in consumption from 385 million gallons per day to 852 over the same period (1.46 million cubic meters per day to 3.23). Land requirements vary less dramatically, rising from 34.1 thousand acres to 89.8 thousand acres (136.7 square kilometers to 359.1), mainly from the opening of new sites for generating unit additions.

Should the load growth deviate from the moderate case to the either extreme, the water and land requirements could be radically different. For the Study Area in 2020 the withdrawals for the historical growth are over 2½ times that for the low-load growth. The ratio of consumptive losses between these extremes is almost 3, and the land use ratio is over 5. The huge land use variation comes from the intensified necessity under a high growth rate to build plants at new sites after exhausting the room at existing sites for new units.

A shift in either the fossil nuclear mix or closed-cycle/once-thru mix would alter the cooling water requirements considerably. The tabular figures for 2020 reflect the use of closed-cycle cooling beyond 1985 and a mix of approximately 55% nuclear to 45% fossil steam capacity. For the moderate case in 2020, the tabulation below gives approximate water requirements in the Chesapeake Bay Study Area for various fossil/nuclear and closed-cycle/once-thru mixes.

ESTIMATED WATER REQUIREMENTS IN THE CHESAPEAKE BAY STUDY AREA FOR VARIOUS CAPACITY AND COOLING MIXES, 2020.

Withdrawal (million gallons per day; million cubic meters per day)

	all fossil	projected mix	all nuclear
all closed cycle	791; 3.00	1279; 4.85	1717; 6.51
all once-thru	44496;168.64	70937;268.85	94612;358.58

Consumption (million gallons per day; million cubic meters per day)

	all fossil	projected mix	all nuclear
all closed cycle	527;2.00	852;3.23	1144;4.34
all once-thru	292;1.11	454;1.72	606;2.40

Table 13-15

SENSITIVITY OF LAND AND WATER USE TO LOAD GROWTH IN THE CHESAPEAKE BAY STUDY AREA, 2000 and 2020

Growth Curve	Water Requirements* Withdrawal (MGD;MCD)	Water Requirements* Consumption (MGD;MCD)	Plant land Area* (KA;km²)
	2000		
Chesapeake Study Area			
Low load growth	7443;28.18	318;1.20	28.1;112.8
Moderate growth	8979;34.03	385;1.46	34.1;136.7
Historical growth	11478;43.44	503;1.90	44.6;179.0
Chesapeake East			
Low load growth	1967; 7.45	77;0.29	7.0; 28.3
Moderate growth	2354; 8.90	92;0.35	8.4; 34.0
Historical growth	2931;11.09	115;0.43	10.5; 42.5
Chesapeake West			
Low load growth	2765;10.47	148;0.56	13.4; 53.6
Moderate growth	3402;12.89	182;0.69	16.5; 66.0
Historical growth	4892;18.52	262;0.99	23.7; 94.9
Chesapeake South			
Low load growth	2711;10.26	93;0.35	7.7; 30.9
Moderate growth	3223;12.22	111;0.42	9.2; 36.7
Historical growth	3655;13.83	126;0.48	10.4; 41.6
	2020		
Chesapeake Study Area			
Low load growth	921; 3.48	613;2.32	64.7;259.8
Moderate growth	1279; 4.85	852;3.23	89.8;359.1
Historical growth	2560; 9.69	1705;6.45	179.5;719.9
Chesapeake East			
Low load growth	163; 0.62	109;0.41	15.8; 63.9
Moderate growth	225; 0.85	150;0.57	21.8; 86.9
Historical growth	396; 1.50	265;1.00	38.5;155.8
Chesapeake West			
Low load growth	453; 1.71	301;1.14	30.2;120.8
Moderate growth	619; 2.35	412;1.58	41.3;165.2
Historical growth	1524; 5.77	1014;3.84	101.7;406.8
Chesapeake South			
Low load growth	305; 1.15	203;0.77	18.7; 75.1
Moderate growth	435; 1.65	290;1.10	26.7;107.0
Historical growth	640; 2.42	426;1.61	39.3;157.3

*MGD=millions of gallons per day KA= thousands of acres
MCD=millions of cubic meters per day Km² = square kilometers

CHAPTER IV

MEANS TO SATISFY ELECTRIC POWER NEEDS

In Chapter III one plausible pattern of future load requirements and power supply was presented based on reasonably expected economic and technological developments in the Chesapeake Bay Market. That portrayal is but one possibility of what may develop. By suitable extensions of utility technologies and applications of new philosophies of service modification, the land and water use indicated might be altered dramatically. The sections which follow explore some of the areas where such modifications could appear.

WATER USE

Steam-electric plants operate by a thermal cycle generally between about 1100 F (600C) and 250 F (120C), these being the turbine inlet and outlet steam temperatures. This range offers an theoretical maximum thermal efficiency of some 55%, the remaining 45% of the energy being rejected as heat. Actual efficiencies, including the mechanical and electrical losses, are about 40% for fossil plants and about 35% for nuclear plants. The lower efficiencies for nuclear plants result from the lower inlet steam temperatures characteristic of current reactor design. These efficiencies are typical for the newest and largest plants; older, and generally smaller, plants have lower efficiencies, running as low as 25% for those relegated to peaking service.

The continued dependence on the thermal process to produce electricity, demands the increasing use of Chesapeake Bay water for steam condensing purposes. Either the water is returned to the Bay in a heated condition for a once-through system or is lost at an increased rate to the atmosphere in a cooling tower system. Reduction of the water volumes so heated or consumed may be accomplished by increasing steam-electric efficiencies or by changing the generation mix to reduce the water requirement, either with existing technology or by introducing new technologies. Increased waste heat utilization could also have beneficial affects.

IMPROVED STEAM-ELECTRIC EFFICIENCIES

Improving the efficiency of the steam cycle is largely a matter of technological development in the area of materials design and heat transfer mechanisms. Improved boiler, turbine, piping, and condenser design might possibly achieve greater conversion efficiencies, given present typical inlet steam conditions. The development of better metals and other suitable materials could allow increased inlet steam temperatures and pressures, thereby raising the theoretical thermal efficiency and making possible a reduced production of reject heat corresponding to the same amount of electrical energy generated.

The ongoing research into improving the nuclear process, including investigations of both thermal and nonthermal energy transfer, is also expected to lessen the disparity between nuclear and fossil steam-plant efficiencies and the resultant water use.

The diversion of power plant generation to operate plant environmental equipment such as scrubbers, high efficiency precipitators, and cooling towers or spray ponds, will place additional demands upon the need for generation and therefore water. Although data are not available to quantify the effects, wide-spread use of environmental equipment could well offset any gains in conversion efficiencies that could be expected through the year 2020 with current generation technology.

CHANGING THE GENERATION MIX

Hydroelectric and combustion plants could to a limited degree be substituted for steam-electric **capacity** with the view of saving water but, with the lack of suitable hydroelectric potential in the near term future, only combustion plants could be realistically considered for the replacement. Combustion plants are air-cooled, jacket-cooled, or free to radiate into the ambient atmosphere and therefore create little demand for water.

With current design, combustion units can be configured into plants of appreciable size; they generally do not approach the large capacity blocks represented by the steam-electric units. Furthermore, combustion plants require a high grade of oil, expensive and volatile in supply, are thermally less efficient than steam units, and are generally designed for limited operation.

Other generating modes, not now operating, could be brought into service in the long term future. Such devices as magnetohydrodynamics, windmills, and solar cells use no water to speak of and may, conceivably, be brought into use early in the next century.

UTILIZATION OF REJECT HEAT

To a small extent, reject heat is presently put to beneficial use by providing exhaust or bleed steam for industrial and commercial purposes. Superficially, it would appear that much of the industrial processes using low temperature steam could benefit from a generating plant's steam exhaust in lieu of producing fresh steam in separate boilers. Actually, such opportunities are now rare but selected future industrial development might possibly be coordinated with the scheduling of generating plants to create an "industrial park" centered on the plant.

Heated cooling water could also be confined in basins and used for aquicultural development, fed into irrigation nets for winter frost prevention, or delivered to waste treatment plants to enhance their biological activity, among other things. After the residual heat energy had been extracted by these uses, the water could be returned to the surface water body with minimal thermal impact.

LAND USE

Virtually all present electric power facilities are located above ground on sites dedicated for the single purpose of the particular facility. When power plants were small and line voltages low the amount of land taken by plants and lines was modest. In Chapter III, future electric power land use was approximated based on typical dimensions and samplings. The resultant order of demand for land in the Chesapeake Bay suggests a need for additional consideration of these requirements. In addition to actions for modifying load growth, the demand for land might be reduced by additional redevelopment of existing sites, more compact design of apparatus, multiple use of future sites and rights-of-way, and underground construction. Utility systems have historically examined all such approaches as a function of economics but a land management program might benefit from refocusing and concentrating efforts in this direction.

REDEVELOPMENT OF EXISTING SITES

Most of the existing power plants in Chesapeake Bay are located in metropolitan areas. Generally, these plants have been long established and contain a range of unit sizes and ages. For the most part, utilities have recently tended to retire their inner city plants and convert the land to other utility use such as substations, storage yards, and shops, while new generating plants were constructed beyond the metropolitan limits. In a few cases when the steam-electric units are retired, combustion units on the site are kept and, at times, additional peaking units are added. Examination of the utilization of these sites may offer opportunities for additional optimization.

Remote sites, far from large cities, are kept and expanded as utility load grows. Because most of these are new sites, expanding is usually a matter of adding a second or third unit comparable to the first unit. The property area and certain common facilities are generally laid out for such future additions and review of the facilities layout might offer opportunities for reduced land use.

Transmission rights-of-way can be redeveloped by reconductoring the towers for a higher voltage and by constructing circuits parallel to the existing circuits, either on the same towers or parallel to existing towers. In both cases of paralleling, provision for doing so can be made when the original right-of-way is cut through and towers are set up, but where this has not been done opportunities for increasing right-of-way utilization may exist.

COMPACT EQUIPMENT DESIGN

Designing equipment to deliver more service per unit of surface land area can, obviously, reduce land requirements. Historical trends in generation have exhibited this through the replacement of multiple, modest capacity unit with single new units of greater capacity but smaller overall land requirements. A continuation of the trend toward compact design of generating units will depend on the continued development of suitable metals and other materials to accomodate higher temperatures and pressures as part of the quest for greater energy conversion efficiencies. Hence, as the new plant designs incorporate efficiency-enhancing features, it is reasonable to expect that the bulk and surface area occupied will decrease.

Current pressures to burn coal and to generate electric power with a minimum of impact on the environment will tend to generate requirements for land to offset gains made through improved efficiencies. Accordingly, efforts directed toward reducing the land requirement for coal storage and handling, related ash disposal, stack clean-up facilities and closed-cycle cooling systems could generate benefits in reduce land requirements.

MULTIPLE USE OF SITES

Present utility land use is essentially single-purposed. Land demand could be reduced by increasing the routing of transmission in corridors already developed, as those for highways and railroads. Although an existing nonelectric right-of-way will rarely connect the terminal of a proposed transmission line, segments of such rights-of-way when assembled with exclusive utility corridors can still effect significant savings. Alternatively, where economic development is extended into a new quarter, the utility's line routing could be modified to coincide with those of other services in a new common corridor. Long term benefits could also result from joint construction of generating plants and an energy intensive service facility. The two could be either a single integrated

edifice producing electricity and, say, fresh water or primary metals or two adjacent facilities operating under contracted agreements. Possibilities for such joint utility-nonutility operation include desalination, garbage reduction, metal refining, petroleum fraction, and chemical mills.

UNDERGROUND CONSTRUCTION

In Chesapeake Bay, transmission lines are placed underground only in the densest metropolitan areas. The existing circuits are limited to the lower voltages and to short lengths and the scheduled transmission additions include few new underground segments.

Underground transmission over long distance at high voltages is today still a technology under development. The thrust of current investigations revolves around increasing the power capacity of the line to a point where its cost of installation is comparable to that of equivalent overhead lines. Possible means of doing this include improved insulative coverings of the cables, forced cooling, gas insulation, and cryogenic superconducting materials.

While, in time, placement of new transmission lines underground, and perhaps some conversion of the overhead lines in certain prescribed areas will reduce the land requirement for utility property around the Bay, underground construction of generating plants is conceded to be rather unrealisitic throughout the study period. Off-shore siting on artificial islands built off the coastline could support clusters of large-sized units connected to land by underwater cable. There are none scheduled in the Chesapeake Bay Study Area but beyond the year 2000 such siting could be considered.

LOAD MANAGEMENT

Though load management could be identified as one of the factors to be used to depress demand, i.e., one of the factors used to hold utility growth to the low or moderate estimates, it can also be viewed in terms of modifying demand and load factor to reduce land and water requirement for whatever energy growth is experienced. Historically the demand for electric energy has been an outgrowth of the overall economic and social climate of the utility's territory. All demand was supplied in full without qualification other than economic return. In the interest of minimizing the water and land use necessary for electric power generation, socially approved demand manipulation and modification might be feasible. Among the possible means

of accomplishing this end are adjusting rate scheduling to effect time-of-day use penalties (peak load pricing) and increasing end-use efficiencies.

ADJUSTING USE-CATEGORY RATE SCHEDULES

Virtually all present day rate tariffs encourage energy use by lowering the unit price of energy as the consumption increases and by maintaining constant rates regardless of the time of day or season of year. It may be possible to modify the tariffs to compress the disparity of low and high consumptive costs, tempering the economic urge to increase overall usage. Some believe that a regressive tariff increasing rates above a certain adjudicated minimum allowable consumption and imposing a prohibitively high rate at high levels of consumption can restrain the unlimited expansion of use. The major obstacles in implementing such an approach revolve around complex legalities and socioeconomic implications.

Another possibility in restructuring rate schedules is the introduction of time dependency. The cost of producing electricity, and the ecological effects of such production, varies throughout the day and year. By inserting a billing term employing time, the price of the electricity can better convey to the consumer the costs associated with his demand for service and could encourage him to adjust his use toward the lower-priced periods of the day or year. Some movement in this direction is already evidenced in the advocation of summer/winter differentials and "night power" rates.

INCREASING END-USE EFFICIENCIES

Much of the electrical energy purchased by the consumer is never transformed into useful work but, is lost in the conversion process employed by the various appliances and equipment. Part of the loss is due to the design of the apparatus and part is due to the operation of the apparatus by the consumer.

By encouraging manufacturers and consumers to consider overall lifetime operating costs as well as first cost capital outlay, more efficient apparatus could be marketed with a resultant reduction in demand. Increased education regarding effective appliance use and maintenance, emphasizing the additional monetary and ecological costs of wasteful equipment, could enhance consumer demand reduction. Proper utilization of natural sunlight and air currents coupled with revised insulating requirements could significantly affect reductions in energy consumption, alleviating the need for electric power facilities.

CHAPTER V

REQUIRED FUTURE STUDIES

In this Study the present and possible future impact of the electric power industry were presented as based on methods and assumptions explained in the several chapters. In many areas the processes by which the water and land requirements were established brought out the need for further investigations.

In discussing water requirements and impacts by utilities, it has heretofore been generally assumed that depositing heated cooling water degrades the resource value of the receiving water body. While for limited and specific uses of the water body the addition of heated water may be harmful, there is no firm evidence that there is any overall deterioration of resource quality. Yet legislation is already in force limiting or prohibiting the discharge of heated water. Studies are needed to definitively circumscribe the nature of discharge impact on water resources.

In trying to model an integrated pattern of water and land use, available reported data for the various categories of use would have to be collected and assembled. For water use, the electric utility contribution is quite well documented in reports filed with the Federal Power Commission; the material for this Study is very largely founded on these reports. For other use categories, data are collected on other bases, for other parameters, and for other immediate purposes. Combining this mixture of use data leads to conflicts and inconsistencies, many of which could prove irreconcilable. Studies are needed to first determine what parameters of water use are necessary for policy making input, and then to structure a mechanism of acquiring these data from all relevant water users on a common basis.

Similar problems relate to land use. For the Electric utility industry, land use for power facilities is rather poorly documented and most of the land use treatment in this Study was based on rough estimates. Hence, studies for parameter definition and data acquisition are needed.

Additionally, the impact of electric power on the Chesapeake Bay Study Area will depend upon the state-of-the art electric power generation. Studies to critically evaluate ongoing research and development programs for such technologies as low BTU coal gasification, fluidized bed combustion, solid waste combustion, advanced gas turbine steam cycle, high temperature gas cooled reactors (HTGR), liquid metal fast breeder reactor (LMFBR), and fuel cells could prove helpful in expediting possible improvement of existing modes of generation. Increased investigations of new sources of energy such as fusion, wind, and solar power could also advance their development and possibly advance their contribution to the future energy needs of the Study Area.

Finally any small substantial action by the utility industry to alleviate its demand for Chesapeake Bay resources reasonably implies economic and social adjustments among the inhabitants of the Bay. Studies to ascertain and rank these must be undertaken before they fall due in an uncontrolled manner.

REFERENCES

Published by US Federal Power Commission:

1970 National Power Survey-Parts I, II, III, IV, 1971

Statistics of Privately Owned Utilities in the United States-1972, 1973

Statistics of Publicly Owned Utilities in the United States-1972, 1973

Sales of Firm Electric Power for Resale-1968-1972, 1974

National Electric Rate Book-Delaware, Maryland and District of Columbia, Virginia, 1973

Typical Electric Bills, -1973, 1974

Planning Status Report-Susquehanna River Basin and Chesapeake Bay Area, and Potomac River Basin, 1967

All-Electric Homes, Annual Bills-1973, 1974

Steam-Electric Plant Construction Cost and Annual Production Expenses-1972, 1974

Gas Turbine Electric Plant Construction Cost and Annual Production Expenses-1972, 1975

Hydroelectric Power Resources of the United States, Developed and Undeveloped-1972, 1972

Hydroelectric Plant Construction Cost and Annual Production Expenses-1972, 1975

Steam-Electric Plant Air and Water Quality Control Data-1972, 1975

Principal Electric Facilities-Map I, 1974

Federal Power Commission Interests in Environmental Concerns Affecting the Electric Power and Natural Gas Industries, 1969

Measures for Reducing Energy Consumption for Homeowners and Renters, 1975

Energy Conservation-It Benefits All of Us, 1974

Electric Power Transmission and the Environment, 1971

Managing The Power Supply and The Environment, 1971

Problems in Disposal of Waste Heat from Steam-Electric Plants, 1969

Federal and State Commission Jurisdiction and Regulation of Electric, Gas, and Telephone Utilities, 1973

Published by Others

Electric Power and the Environment, Office of Science and Technology, 1970

Annual-Statistical Report, Rural Electrification Administration, 1972,

Statistical Year Book-1972, Edison Electric Institute, 1973

Steam-Electric Plant Factors-1973 edition, National Coal Association, 1974

The Electric Utility Industry and the Environment, Electric Utility Industry Task Force on Environment, 1968

GLOSSARY

The definitions of the following terms are specially directed to this Chesapeake Bay Study and, therefore, may not be precisely those used for similar terms elsewhere.

Base-Load:	An adjective denoting the continuous, or nearly continuous, operation of a generating plant at or near its capability.
Bulk Power:	a general concept alluding to the generation and transmission of large amounts of energy to supply the requirements of a group of utilities operating in a coordinated and integrated manner.
BTU:	the abbreviation for "British Thermal Unit", a standard unit of measuring quantity of heat energy. It is the amount of heat energy necessary to raise the temperature of one pound of water one degree Fahrenheit and approximately equals 0.2928 watthour of electrical energy.
Capability:	the maximum load which a generating unit, generating station, or system can carry under specified conditions for a given period of time, without exceeding approved limits of temperature and stress on electrical apparatus, expressed in megawatts in this Study. This may differ from the Nameplate Capacity

Capacity:	(1) a general concept alluding to having or constructing generating plants or transmission interconnections to secure the ability to provide electric power.
	(2) same as Nameplate Capacity.
Cooling Tower:	an apparatus in a generating plant wherein the heated cooling water is cooled and return to the condenser for reuse. The cooling may be accomplished by spraying, fanning, or other means.
Cooling Water:	the water passed through a condenser in a generating plant to remove heat from exhaust turbine steam.
Condenser:	a device in a generating plant in which turbine exhaust steam is transformed back to water and returned to the boiler for reuse.
Customer:	an individual, firm, organization, or other electric utility which purchases electric service at one location under one rate classification, contract, or schedule.
Cycling:	an adjective denoting the operation of a generating plant on a daily or weekday cycle to supplement the base-load generation of other plants.
Demand:	same as Load (1)
Efficiency:	a measure of energy "utilization" in a generating unit, generating station or system equal to the ratio of the useful energy output to the energy input under specified conditions.

Electric Power: (1) the time rate of generating, transmitting, or consuming electrical energy.

(2) the general concept of a service whereby electrical energy is made available to customers for lighting, heating, and other purposes.

Electric utility: an enterprise engaged in the production and/or distribution of electricity for use by the public.

Electric Utility Industry: the collection of electric utilities, together with appropriate supporting industries and organizations, by which coordinated, economical, and reliable electric power is provided.

Electrical Energy: energy produced, delivered, or consumed as current electricity.

Energy: (1) the quantity of electrical energy consumed by the customers, by miscellaneous internal uses, and by the losses of a utility or group of utilities measured in gigawatthours in this Study. It is equal to the generation, plus the net receipts from other utilities, of the utility or group.

(2) the physical concept of accomplishing work or having the wherewithal to do so.

(3) same as Electrical Energy

Energy Requirements:	same as Energy (1)
Firm Power, Firm Service:	the electric power or power-producing capacity supplied by a utility to a customer under contract and intended to be available at all times during the period covered by the commitment, even under adverse conditions.
Fossil-Fired:	an adjective denoting the use of coal, oil, or gas as the primitive energy source or raw fuel to be used in the conversion of heat energy into electrical energy in a generating plant.
Fossil Fuel:	combustile material extracted from the earth and used in generating plants; so called from its creation from fossile animals and plants in extreme geological conditions. There are only three main fossil fuels used by the utility industry: coal, oil, gas.
Fuel Adjustment Clause:	a clause in a rate schedule that provides for an adjustment of the consumer's electric power bill to reflect the variation of the cost of fuel at the utility's plants from a specified base unit cost.
Generating Plant, Generating Station:	a facility, at which are located prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or nuclear energy into electrical energy which is then ultimately delivered to consumers.
Generating Unit:	an electric generator together with its prime mover and auxiliary equipment.
Generation:	(1) the quantity of electrical energy produced by a generating plant or group of plants, measured in gigawatthours in this Study. (2) the act or process of producing electrical energy from other forms of energy by means of generating plants. (3) same as Capacity (1)

Gigawatthour:	the unit of energy equal to 1 billion (or 1 thousand million) watthours, the Watthour being an exceedingly small unit.
Head:	the difference between the high and low side water elevation across a hydroelectric plant, through which water falls to produce electrical energy in the plant.
Heat Rate:	A measure of generating plant thermal efficiency equal to the ratio of the total amount of fuel energy burned to the resulting net quantity of electrical energy generated; measured in megatthours (thermal) per megawatthour (electrical) in this Study.
High Voltage	a voltage level equal to or above 138 kilovolts, used for transmitting electrical energy.
Hydro, Hydroelectric:	an adjective denoting the use of falling water as the primitive energy source to be converted into eletrical energy in a generating plant.
Interconnection:	the connection by transmission line of two utilities or groups of utilities by which electrical energy may be transferred from the one to the other.
Kilovolt:	the unit of electromotive force or electrical "pressure" equal to 1000 volts, the Volt being a rather small unit.
Load:	(1) the amount of electric power delivered or required at any specified point or points on a system. Load originates primarily at the power consuming equipment of the customers. See Demand. (2) the general concept alluding to both demand and energy as figures of measure for electric power requirements.

Load Center:	a geographical location, typically a city or industrial district, at which the load of a given area is assumed to be concentrated.
Load Factor:	a measure of "utilization" by a customer, utility, or group of utilities over a specified time span, equal to the ratio of the energy requirements to the product of the peak demand and the number of hours in the time span, expressed as a percent by equation:

$$\text{load factor } (\%) = \frac{(\text{energy in watthours})}{(\text{peak in watts}) \times (\text{hours})} \times (100\%)$$

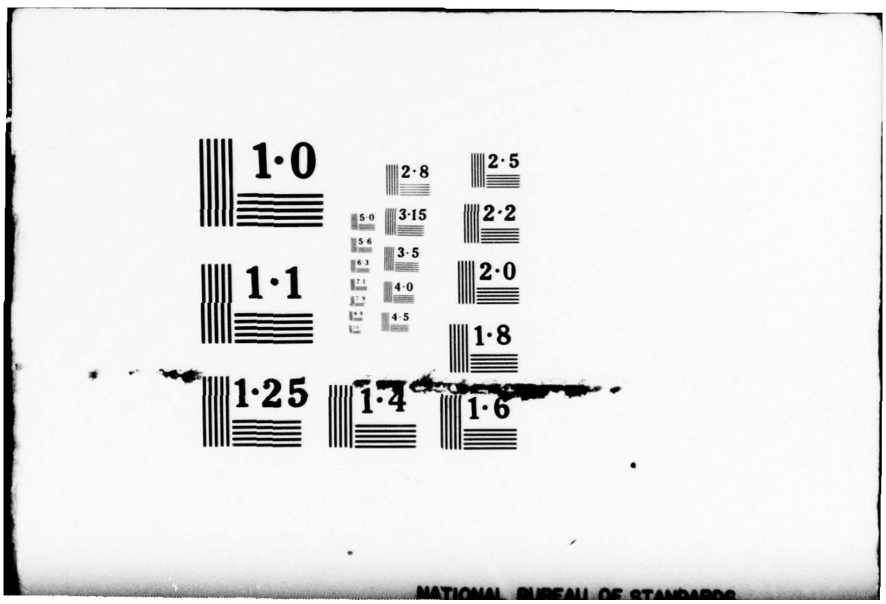
Market Area:	a geographical delineation of the contiguous service areas of utilities bordering the Chesapeake Bay, used as a statistical framework for this appendix and this Study.
Megawatt:	the unit of power equal to 1 million watts, the Watt being a very small unit.
Nameplate Capacity:	the full-load continuous rating of a generating unit under specified conditions as designated by the manufacturer, usually indicated on a name plate attached mechanically to the unit, expressed in megawatts in this study. This may differ from the Capability of the unit.
Nuclear, Nuclear-Fired:	an adjective denoting the use in a generating plant of energy produced in the form of heat during the fission process in a nuclear reactor. This heat energy, when released in sufficient and controlled quantity, is used to produce steam to drive a turbine-generator and thus is converted to electrical energy.
Nuclear Fuel:	Material extracted from the earth containing fissionable materials of such composition and enrichment that when placed in a nuclear reactor will support a self-sustaining fission chain reaction and produce heat in a controlled manner for process use. Presently, only uranium and plutonium are the nuclear fuels used by the utility industry.

AD-A052 480 CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT F/G 6/6
CHESAPEAKE BAY FUTURE CONDITIONS REPORT. VOLUME 10. POWER, NOXI--ETC(U)
DEC 77

UNCLASSIFIED FCR-77-010 NL

2 OF 2
ADA
052480

END
DATE
FILMED
5-78
DDC


1·0
2·8
2·5
3·15
2·2
3·5
1·1
2·0
4·0
4·5
1·8
1·25
1·4
1·6

Outage:	(1) the removal from available service of a generating unit, transmission line or other facility for inspection or maintenance in accordance with an advance schedule, or due to breakdown and other emergency conditions. (2) the period during which such facilities are unavailable for service because of such removal.
Peak, Peak Demand:	the greatest or maximum demand for electrical energy which has occurred during a specified time span.
Peak-Load, Peaking:	an adjective denoting normal operation of a generating plant only during periods of peak demand.
Plant:	same as Generating Plant
Power:	(1) same as Electric Power (2) the physical concept of energy rate of production, delivery, or consumption.
Power Pool:	two or more interconnected electric systems planned and operated on a coordinated basis to supply power in the most reliable and economical manner for their combined load requirements and maintenance program.
Power Plant:	same as Generating Plant.
Prime Mover:	the device with which fuel or water energy is converted into mechanical energy to drive an electric generator. There are 5 prime mover categories used: fossil steam, nuclear steam, hydroelectric, pumped-storage, and all-other.
Pumped-Storage Plant:	a generating plant utilizing an arrangement whereby electric energy is generated for peak load use by hydraulic means using water pumped into a storage reservoir usually during off-peak periods.

Pumping Energy: the energy required by a pumped-storage plant to pump water into a storage reservoir. This water is released to provide electric power at a future time. The ratio of the pumping energy to the resulting electric energy produced is usually in the order of 3:2.

Reject Energy, Reject Heat: the fraction of the fuel energy which during its conversion into electrical energy by means of a thermocycle is unavailable for such conversion and is discharged from the conversion cycle as heat. The magnitude of this fraction is governed by the Second Law of Thermodynamics and the efficiency of the cycle.

Reserves: the amount of capacity installed on a utility's system over the peak demand of the utility, either actually experienced or anticipated for the future, measured both in megawatts and percent-of-peak in this Study. It is the margin of capability available to provide for scheduled maintenance, emergency outages, system operating requirements, and unforeseen loads.

Service Area, Service Territory: an exclusive geographic area or territory in which a utility system is required or has the right to supply or make available electric service to ultimate consumers.

Siting: the general concept alluding to the selection and utilization of suitable locations for generating plants or transmission lines.

Steam, Steam-Electric: an adjective denoting the use of steam in an electric generating plant as the motive force of its prime mover. The steam is generated by heat from burning fossil fuels or from the fissioning of nuclear fuel.

Substation: a facility consisting of an assemblage of equipment for the purpose of switching and/or changing or regulating the voltage of electricity.

System:	a physically connected network of facilities, including generating plants and transmission and distribution lines, operated as an integral unit under one control, management, or operating supervision for providing electric power.
Thermocycle:	a process in which a suitable machine accepts the fuel energy in the form of high temperature heat energy and discharges both useful work in the form of electrical energy and reject energy in the form of heat energy of lower temperature.
Thermal, Thermo:	an adjective, or a prefix, denoting the use of a thermocycle for the production of electrical energy; a type of electric generating plant or the capacity or capability thereof, in which the source of energy for the prime mover is heat.
Transmission:	(1) a functional classification related to that portion of utility plant used for the purpose of transmitting electric energy in bulk to other principal parts of the system or to other systems. (2) the act or process of transporting electric energy in bulk from a source or sources of supply to other principal parts of the system or to other utility systems. Ordinarily the transmission process is considered to end when the energy is transformed for distribution to ultimate consumers.
Transmission Line:	a facility, typically towers or poles carrying conducting wires, over which energy is transferred from one place to another.
Unit:	(1) Same as Generating Unit (2) a quantity or particule of measure (3) a set or collection of equipment considered as a single entity.

Utility:	same as Electric Utility.
Utility Industry:	same as Electric Utility Industry.
Volts:	the fundamental physical unit of electromotive force or "pressure", analogous to pressure in mechanics or fluid dynamics.
Voltage:	the electromotive force or "pressure" at which electrical energy is produced, transmitted, or consumed. The voltage levels used by the utilities in this Study for bulk power functions are 138, 230, 345, and 500 kilovolts.
Watt:	the fundamental physical unit of power or the time rate of producing, transmitting, or consuming electrical energy.
Watthour:	the fundamental physical unit of electrical energy, equivalent to 1 watt of power acting over 1 hour of time.

CHESAPEAKE BAY
FUTURE CONDITIONS REPORT

APPENDIX 14

NOXIOUS WEEDS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
THE STUDY AND THE REPORT

The Chesapeake Bay Study developed through the need for a complete and comprehensive investigation of the use and control of the water resources of the Bay Area. In the first phase of the Study, the existing physical, biological, economic, social, and environmental conditions and problem areas were identified and presented in the *Existing Conditions Report.* The *Future Conditions Report* of which this appendix is a part, presents the findings of the second or projections phase of the Study. Included as part of the second phase were the projections of future water resource needs and problem areas, identification of general means that might best be used to satisfy those needs, and development of recommendations for future studies and hydraulic model testing. The results of this phase of the Study and this report constitute the next step toward the goal of developing a comprehensive water resource management program for Chesapeake Bay.

Chesapeake Bay serves as a vast natural asset to the surrounding land area. Along with its tributaries, the Bay provides a natural transportation network on which the economic development of the Region has been based, a wide variety of water-oriented recreational opportunities, a source of water supply for both municipalities and industries, and a rich habitat and nursery for fish and wildlife. All of the resources provided by the Bay interact with each other in forming the Chesapeake Bay Ecosystem. Unfortunately, problems often arise when man's use of one resource conflicts with either the natural environment or man's use of another resource.

Because of the many resources that the Bay has to offer, extensive development has occurred along its shoreline. Industries have taken advantage of the transportation network offered by the Bay and have located manufacturing and shipping facilities along the shoreline. The increased demand for waterfront home sites in recent years has also accounted for widespread development. As a recreation resource, the Bay and its tidal tributaries provide an extensive area for boating, swimming, and sport fishing. Conflicts often arise when man's intended use of the Bay and its resources is disrupted or limited by the natural environment. For example, the presence of natural growths of certain species of aquatic plants can limit the recreational use or aesthetic value

(cont from p.1 appendix 13)

Appendix 14

of Bay waters. This particular volume "Noxious Weeds," focuses on problems related to aquatic plants. A discussion of the types of problems and the factors affecting the growth of the troublesome species within the Region is provided in this appendix. Various means of controlling infestations of undesirable aquatic plants are discussed and the future studies that are required to develop an aquatic plant control program for Chesapeake Bay are identified.

AUTHORITY

The authority for the Chesapeake Bay Study and the construction of the hydraulic model is contained in Section 312 of the River and Harbor Act of 1965, adopted 27 October 1965, which reads as follows:

> (a) The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a complete investigation and study of water utilization and control of the Chesapeake Bay Basin, including the waters of the Baltimore Harbor and including, but not limited to, the following: navigation, fisheries, flood control, control of noxious weeds, water pollution, water quality control, beach erosion, and recreation. In order to carry out the purposes of this section, the Secretary, acting through the Chief of Engineers, shall construct, operate, and maintain in the State of Maryland a hydraulic model of the Chesapeake Bay Basin and associated technical center. Such model and center may be utilized, subject to such terms and conditions as the Secretary deems necessary, by any department, agency, or instrumentality of the Federal Government or of the States of Maryland, Virginia, and Pennsylvania, in connection with any research, investigation, or study being carried on by them of any aspects of the Chesapeake Bay Basin. The study authorized by this section shall be given priority.
>
> (b) There is authorized to be appropriated not to exceed $6,000,000 to carry out this section.

An additional appropriation for the study was provided in Section 3 of the River Basin Monetary Authorization Act of 1970, adopted 19 June 1970, which reads as follows:

In addition to the previous authorization, the completion of the Chesapeake Bay Basin Comprehensive Study, Maryland, Virginia, and Pennsylvania, authorized by the River and Harbor Act of 1965 is hereby authorized at an estimated cost of $9,000,000.

As a result of Tropical Storm Agnes, which caused extensive damage in Chesapeake Bay, Public Law 92-607, the Supplemental Appropriation Act of 1973, signed by the President on 31 December 1972, included $275,000 for additional studies of the impact of the storm on Chesapeake Bay.

PURPOSE

Previously, measures taken to utilize and control the water and land resources of the Chesapeake Bay Basin have generally been toward solving individual problems. The Chesapeake Bay Study provides a comprehensive study of the entire Bay Area in order that the most beneficial use be made of the water-related resources. The major objectives of the Study are to:

a. Assess the existing physical, chemical, biological, economic, and environmental conditions of Chesapeake Bay and its water resources.

b. Project the future water resources needs of Chesapeake Bay to the year 2020.

c. Formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

The *Chesapeake Bay Existing Conditions Report*, published in 1973, met the first objective of the Study by presenting a detailed inventory of the Chesapeake Bay and its water resources. Divided into a summary and four appendixes, the report presented an overview of the Bay Area and the economy; a survey of the Bay's land resources and its use; and a description of the Bay's life forms and hydrodynamics.

The purpose of the *Future Conditions Report* is to provide a format for presenting the findings of the Chesapeake Bay Study. Satisfying the last two objectives of the Study, the report describes the present use of the resource, presents the demand to be placed on the resource to the year

2020, assesses the ability of the resource to meet future demands, and identifies additional studies required to develop a management plan for Chesapeake Bay.

This particular appendix addresses the types of problems associated with excessive growths of aquatic plants in the Bay and its tributaries. As an introduction, and in an attempt to establish the proper perspective on noxious weeds as members of the overall community of aquatic plants, sections of the report address the various types of aquatic plants and the factors affecting their growth. Past problems involving noxious weeds in the Chesapeake Bay Area are also surveyed species by species along with a review of pertinent control measures and the advantages and disadvantages of their use.

SCOPE

The scope of the Chesapeake Bay Study and *Future Conditions Report* includes the multi-disciplinary fields of engineering and the social, physical, and biological sciences. The Study is being coordinated with all Federal, State, and local agencies having an interest in Chesapeake Bay. For each resource category presented in the *Future Conditions Report* demands and potential problem areas are projected to the year 2020. All conclusions are based on historical information supplied by the preparing agencies having expertise in that field. In addition, the basic assumptions and methodologies are quantified for accuracy in the sensitivity section. Only general means to satisfy the projected resource needs are presented, as specific recommendations are beyond the scope of this report.

As shown on Figure 11-1, the geographical area considered in the overall study encompasses those counties or Standard Metropolitan Statistical Area (SMSA) which touch or have a major influence on the Estuary. For purposes of projecting the future demands on the resources of the Bay, economic and demographic projections were made for all subregions and SMSA's within the Study Area. Regarding aquatic plants, however, the actual Study Area included only the Bay and its tidal tributaries and that shoreline area which was influenced by the presence of aquatic plants.

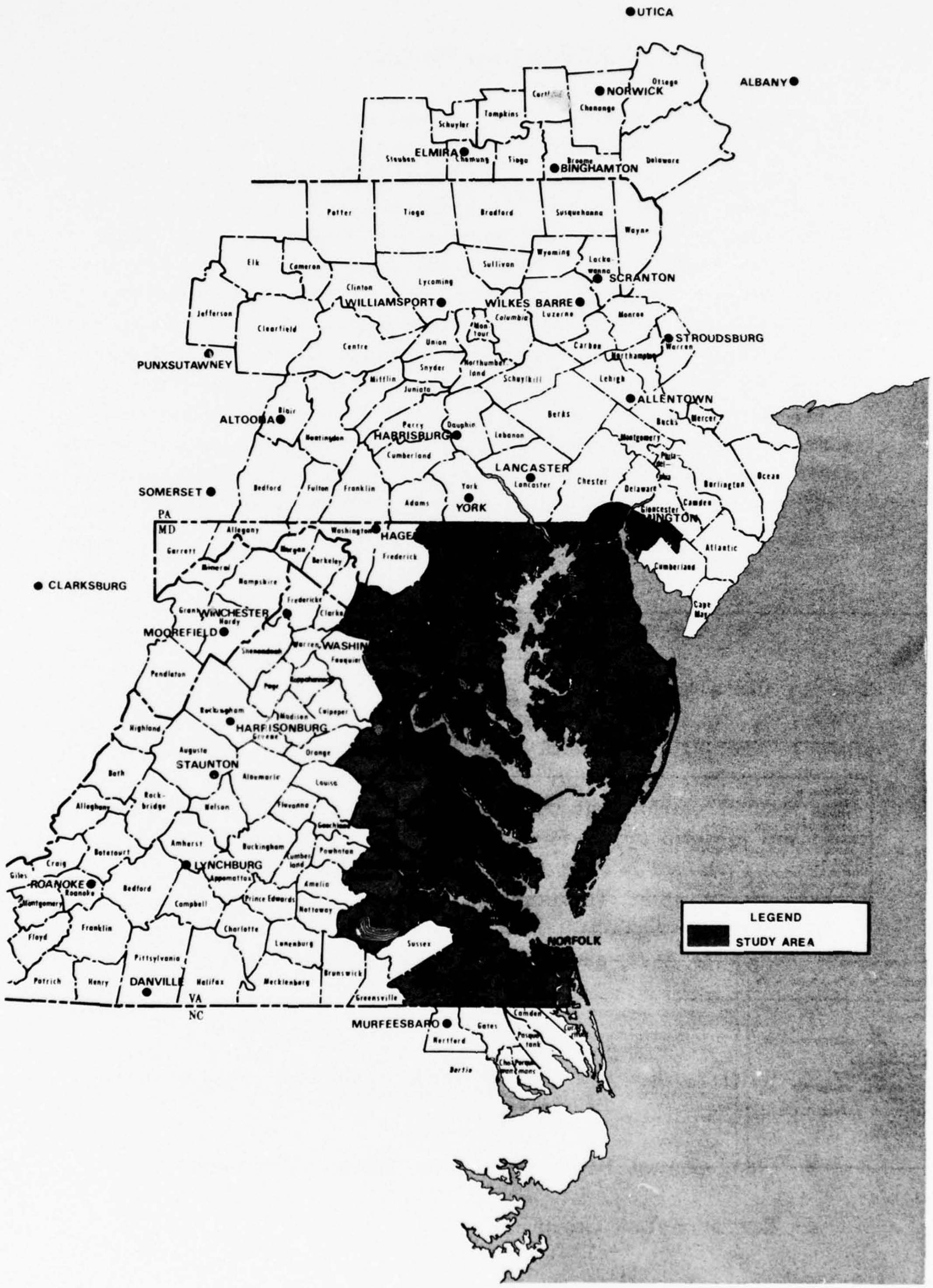


FIGURE 14-1: CHESAPEAKE BAY ESTUARY AREA

SUPPORTING STUDIES

This appendix was coordinated and prepared by the Baltimore District, Corps of Engineers. Much of the information included in this report was taken from or developed using other sources. The initial data base for this particular volume, as well as for all other volumes of this report, was presented in the *Chesapeake Bay Existing Conditions Report*. Other studies that provided a major input to this appendix include the *Reconnaissance Report, Aquatic Plant Control Program* prepared by the Corps of Engineers and numerous technical reports on aquatic plant control measures prepared by the Waterways Experiment Station of the Corps of Engineers. In addition, several publications of the Patuxent National Wildlife Research Center and the State of Maryland, Department of Natural Resources were very helpful. All materials and data used in the appendix are referenced in the Bibliography. For additional information on plant-related topics and a more detailed discussion of the importance of aquatic plants, the reader is referred to Appendix 15–*Biota*.

STUDY PARTICIPATION AND COORDINATION

Due to the wide scope, large geographical area, and many resources covered by the Chesapeake Bay Study, data input was required from many sources. Various Federal, State, and local agencies throughout the Bay Region have customarily developed expertise in certain areas of water resource development. Although overall coordination of the Study effort was provided by the Corps of Engineers, input from these various sources was required in order to obtain the best Study coordination and problem identification. Therefore, an Advisory Group and a Steering Committee were established. Five Task Groups were also formed to guide preparation of reports on related resource categories. They are:

1. Economic Projection Task Group

2. Water Quality and Supply, Waste Treatment, Noxious Weeds Task Group

3. Flood Control, Navigation, Erosion, Fisheries Task Group

4. Recreation Task Group

5. Fish and Wildlife Coordination Group

Detailed information on the composition of each Task Group as well as the members of the Advisory Group is presented in the Chesapeake Bay Plan of Study and in Appendix 1, "Study Organization, Coordination, and History."

This appendix was prepared under the guidance of the Water Quality and Supply, Waste Treatment, and Noxious Weeds Task Group. The Group is chaired by the Environmental Protection Agency. Members of the Task Group include the U.S. Departments of Agriculture, Commerce, Interior, Navy, and Transportation; the Energy Research and Development Administration; the Federal Power Commission; the Corps of Engineers; the Susquehanna River Basin Commission; and representatives of the States of Maryland and Delaware, and the Commonwealths of Virginia and Pennsylvania, and the District of Columbia.

CHAPTER II
AQUATIC PLANTS OF CHESAPEAKE BAY

Marked changes have occurred in the Chesapeake Bay Region since Captain John Smith navigated the Bay in 1608. Where at that time only scattered Indian tribes used the Bay for its fish and wildlife resources, today more than 8 million persons reside in the Bay Area and depend to one degree or another on the Bay's many and varied resources. Because of high biological productivity, the Chesapeake Bay acts as a vast incubator and nursery ground for the aquatic life necessary for propagation of many species of commercial and sport fish.

The high productivity of the Chesapeake Bay Estuary is associated with its production of green plants. Green plants use the inorganic nutrients in the water that cannot be used by organisms in the higher trophic levels. Thus, the plants, ranging from the microscopic algaes to the larger rooted aquatics, are the primary producers–the first link in the aquatic food chain. Food energy is made available for the smaller organisms and fishes in the estuary which in turn provide a food supply for predators and other animals in higher trophic levels.

The rapid growth and development of the Bay Region has caused a coincident increase in the amount of nutrients entering the Bay. This influx of nutrients together with the naturally high quality of the Bay environment has often resulted in excessive growths of aquatic plants. While, as noted above, the Bay's high productivity can be linked ultimately to plant life, excessive growths can have an adverse effect on both the natural environment and man's utility of the water and related land resources.

This chapter provides a brief description of the Bay Region and an overview of the Bay's aquatic plants and the factors that influence their growth. Also included is a discussion of past and present Bay-wide aquatic plant problems and a description of the more troublesome species. Lastly, the Federal and state agencies that have responsibilities regarding the management and control of aquatic plants are identified.

DESCRIPTION OF THE REGION

Chesapeake Bay is one of the largest estuaries in the United States, having a total length of nearly 200 miles and varying in width up to a maximum of about 30 miles near the Maryland-Virginia boundary. The Bay receives freshwater from a drainage area of approximately 64,160 square miles with the Susquehanna, Potomac, Rappahannock, York, and James Rivers providing approximately 90 percent of the total freshwater flows into the Bay. The drainage basin includes portions of Maryland, Virginia, West Virginia, Delaware, Pennsylvania, and New York. The many major and minor tributaries of the Bay system often extend miles inland, making the length of the tidal shoreline total approximately 6900 miles.

Chesapeake Bay, as is typical of most Coastal Plain estuaries, is relatively shallow having a mean depth of less than 28 feet. The geologic features and topography of the Region make the Bay and its tributaries highly susceptible to the process of erosion and subsequent sedimentation. On a long term basis, the natural sedimentation processes are tending to fill the Bay and convert it to a riverine system. The shallow depth and the influx of sediments and nutrients from the large drainage basin all contribute substantially to the productivity of the Region's aquatic plants.

The Bay lies entirely within the Coastal Plain which is characterized by poorly consolidated marine and fluvial sediments. The Bay's Eastern Shore is very flat and low-lying and the shorelands are composed of weakly compacted sands and clays that are very susceptible to erosion from both normal and storm-induced wave action. The Western Shore consists of more rolling terrain with bank heights up to approximately 150 feet. These higher western shore banks are more commonly composed of coarser-grained sediments and are susceptible to erosion by wave induced undercutting and subsequent sluffing of bank material.

The mean tidal fluctuation in the Bay is small, generally between one and two feet. Saline water intrusion is highest along the eastern side of the estuary due to the influence of the Coriolis force. Salinities range from 35 parts per thousand inside the mouth of the Bay to near zero at the north end of the Bay and at the heads of the embayments tributary to the Bay. Salinity variations constitute the most significant

physical parameter influencing the circulation dynamics of the estuary. The wide variation in salinity is also an important factor in the number and distribution of aquatic plants in the Bay.

Development in the Bay Region has generally occurred along the Bay's tidal tributaries which provided natural transportation routes for water-borne commerce. The largest metropolitan areas are located on the Western Shore and include Baltimore, Maryland; Washington, D.C.; and Richmond, Norfolk, Newport News, Hampton and Portsmouth, Virginia. These metropolitan areas contained approximately 80 percent of the approximately 8 million inhabitants of the Bay Region in 1970. Because of the recreational and aesthetic values of the Bay, many Bay residents have either permanent or second homes located along the Bay shoreline. Recreation pursuits and the aesthetic value of certain Bay waters have sometimes been degraded because of infestations of aquatic plants.

The Chesapeake Bay also serves the 8 million Bay Area residents as a vast waste assimilator. Municipal, industrial, and agricultural wastes discharging into the Bay have increased along with the burgeoning population. Presently, most waste discharges are assimilated and water quality problems are restricted to the tributary areas that are adjacent to the highly urbanized areas. Many of the constituents of man-related discharges into the Bay have a significant effect on aquatic plant growth in the Region and can, in fact, both stimulate and retard the growth of many species.

The fish and wildlife resources of the Chesapeake Bay Area are many and varied. The extraordinary extensiveness and diversity of the Bay stand it apart as one of the most productive estuaries on earth. Including land dwellers, the Bay Area provides a home for over 2,700 identified species. Prolific amounts of seafood are harvested commercially with totals equaling 630 million pounds worth $41 million in 1970. Sport yields of finfish and shellfish were estimated to be equal to the commercial catch. The value of these resources to the economy, and indeed to the well-being of mankind, is inestimable.

TYPES OF AQUATIC PLANTS

Aquatic plants exist in the natural environment in a myriad of shapes and forms and degrees of specialization. They also can be found in waters of widely varying physical and chemical quality, and in virtually all climates of the world. Classification of aquatic plants can be based on several criteria, but for purposes of this discussion, they are most conveniently placed in two categories: (1) phytoplankton, and (2) macrophytes.

PHYTOPLANKTON

Phytoplankton (from the Greek: plant + wandering) is a general term used for aquatic plants of both fresh and saline waters which are characteristically free-floating and microscopic. The most important of the phytoplankton are the green algae (phylum Chlorophyta), diatoms (phylum Chrysophyta), and dinoflagellates (phylum Pyrrophyta). The population of these minute, mostly unicellular, organisms is represented by relatively few species, but when they do occur, they are usually present in tremendous numbers. The phytoplankton as a whole are the principal photosynthetic producers in the marine, estuarine, and fresh-water environments, and will grow in the water column to any depth that light will penetrate.

The green algae are represented by widely divergent forms, both uni- and multi-cellular. Some are capable of living even in moist places on land, but most species occur in fresh water. Visible to the casual observer only as a greenish tinge in the water, the unicellular green algae respond vigorously to excess amounts of nutrients and may create a "pea soup" condition in lakes and reservoirs. Also of interest is the fact that certain of the unicellular green algae are theorized to be direct descendents of the ancestral organism from which the rest of the plant kingdom arose. Many are still very primitive in their degree of specialization.

Diatoms are another of the general category phytoplankton, most species being unicellular or colonial. A great diversity of shape and ornamentation is exhibited by these organisms, some of which are jewel-like in their appearance. Diatoms are abundant in both fresh and saltwaters and are of particular interest in that they play such an extremely important role in aquatic food chains. Of the marine plankton, the diatoms are the

most abundant component–a gallon of sea water will commonly contain 1 or 2 million diatoms(1).

Dinoflagellates are usually unicellular organisms found primarily in marine as opposed to fresh waters. Compared with diatoms, dinoflagellates tend to dominate more in tropical and subtropical waters. It is of interest to note the diversity and versatility of these organisms. Some act directly as photosynthetic producers; others are completely contrary in that they feed on other living organisms; different still are those that subsist only on dead or decaying organic material.

Some of the species of dinoflagellate are poisonous. Of these, some are red-pigmented and produce the phenomenon known as the "red tide" that has been credited with massive fish kills. Certain of the red tides are a problem not because of their toxicity but because of the oxygen depletion accompanying decay of the large masses of organic material. Although unknown for sure, it is suspected that the red tides may result from organic pollution in conjunction with suitable conditions produced by preceding population explosions or "blooms" of other phytoplankton(2) (50).

Blue-green algae (phylum Cyanophyta) are another type of organism which is difficult to describe as "plant" or "animal," but will be mentioned here due to its importance in the aquatic environment. Biologists have sometimes included it in a new kingdom Monera, where it is included with the bacteria. The blue-green algaes are not considered to be of importance in aquatic productivity, but are best known for the nuisance conditions caused when their growth occurs in excess. Blooms of these organisms may make objects only a few inches below the surface invisible. The blooms may also give off objectionable odors, clog water supply filters, and even be toxic to livestock (1).

MACROPHYTES

As the Greek roots of the word indicate, macrophytes are, very simply, "large plants." Unlike the freely floating (or only weakly motile) and minute phytoplankton, the macrophytic aquatic plants are generally either rooted or otherwise fastened in some manner to the substratum. Included in the general category of macrophytic aquatic plants are the many marsh grasses, sea grasses, multicellular green algaes, sea weeds, pond weeds, duck weeds, and various other forms. Except for some of

the multicellular algaes such as sea lettuce, the macrophytes are largely seed-producing plants (*Spermatophyta*). All of the forms require sunlight to conduct photosynthesis and most have defined leaflets which grow either entirely submerged, floating on the surface of the water, or emergent from the water with leaf surfaces in direct contact with the atmosphere.

SUBMERGED AQUATICS

The submergent forms of aquatic plant life are found in all waterbodies from freshwater ponds to the open ocean. Primary in the freshwater environment is genus *Potamogeton* (pondweeds) which is one of the largest genera of rooted aquatic plants. In the freshwater environment, other important submerged aquatics include coontail, water weed, naiad, wild celery, and certain non-rooted genera usually classified as algae (such as "Muskgrass" or Chara). In addition to their importance in the detrital food chain, many of these plants are valuable as food for waterfowl. However, several species in this group, at times, are also troublesome in parts of the United States, including, coontail, water-milfoil, and elodea (waterweed), and certain of the filamentous green algae, such as *Pithophora*.

In the marine environment, multicellular attached algae or "sea weeds" are the dominant submergent forms. They are found mostly on hard bottoms or in rocky areas with shallow water and are attached to the bottom with hold-fast organs, not roots. Various of the seaweeds are valuable as commercial sources of agar, and, in Japan, certain species are cultured for food (2).

In estuary areas, with characteristic tidal currents and wide variance in salinity concentrations in the water, fewer types of submerged aquatic plants are found. Most submerged plants prefer shallow, quiet water in which to grow. Since salinity in any given location will vary during the day, month, and year, organisms must have a wide tolerance to salinity fluctuations. While grasses in the salt marsh are often the dominant producer, *Zostera Marina*, or eelgrass, is an important submerged estuarine plant which sometimes is the dominant producer. It is, for example, of key importance in portions of Chesapeake Bay, as are several other species, including widgeongrass (*Ruppia maritima*) and horned pondweed (*Zannichellia palustris*) (3). A sufficient number of these plants also cause problems in the Nation's waterways. Some estu-

aries in the United States are plagued with excesses of filamentous algaes, such as *Cladophora*, *Codium* (spaghetti grass), and some of the red algaes. Sea lettuce and watermilfoil are also problem submergents, although both of these have evidenced definite ecological value in certain instances. Some varieties, such as eelgrass, widgeongrass, and others, which are normally a very beneficial part of aquatic ecosystems, also have the potential to become problem species when their growth occurs in excess or in areas that conflict with man-related activities. A detailed discussion of the eelgrass community and a more general discussion of the role of aquatic plants in the Bay ecosystem is presented in Appendix 15: *Biota*

FLOATING AQUATICS

The second type of macrophytic aquatic plant is the rooted plant with floating leaves. In the Eastern United States, these are represented in part by four species of water lilies (*Nymphaea*). The significance of these plants is mainly in their horizontal photosynthetic surfaces which hinder light penetration to the water. Duck weed is another type of plant which floats on the surface of the water. With their tiny round leaflets, they are familiar sights on still freshwater ponds where they form floating islands of vegetation, sometimes obscuring the light source of other aquatic producers in the water column. These plants are also beneficial in that they are a waterfowl food and provide cover for fish, turtles, and amphibians. Water chestnut, an imported pest species found in fresh waters, has growing habits similar to the water lillies, but will grow entirely out of the water when growths of high density occcur.

EMERGENT AQUATICS

The third type of macrophytic aquatic plant is the emergent type, or plants that grow with principal photosynthetic surfaces projecting out of the water. Thus, carbon dioxide for food manufacture is obtained from the air but other raw materials are derived from beneath the water surface. In fact, these plants have been found to be useful "nutrient pumps" in the ecosystem in the manner in which they recover phosphorus from the bottom anaerobic sediments (2). Nearly all the plants in this category are seed-producing, flowering plants (Angiosperms).

Among the more familiar of the emergent plants in the freshwater environment are the cattails, genus *Typha*. The cattails are considered to be a widespread dominant producer in the aquatic environment. Other emergent plants typical of freshwaters are bulrushes (*Scirpus*), arrowheads (*Sagittaria*), burreeds (*Sparganium*), spikerushes (*Eleocharis*), and pickerel weeds (*Pontederia*). In waters of the Southeastern United States, particularly Florida and Louisiana, certain of these plants cause problems in canals, shallow lakes, and bays. Most notably water hyacinth and alligatorweed have been the objective of massive control programs in the aforementioned states.

In estuaries, emergent aquatic vegetation is often the principal primary producer. Most notably, saltmarsh grass *Spartina alterniflora*, is found growing over thousands of acres of salt marsh along the Atlantic Coast. The microbially enriched grass detritus provides "food" for other organisms at higher trophic levels throughout the estuary. In waters of lower salinity, other types of plants emerge along with a higher diversity of species (3). Emergent aquatics also serve in varying degrees as food for muskrat, beaver, nutria, and waterfowl.

FACTORS AFFECTING GROWTH

An understanding of the many factors which affect plant growth is critical to an understanding of plants, their role in the environment, and how aquatic plant problems might best be approached in the comprehensive management of the resources of Chesapeake Bay.

In the study of biological systems, the concept of primary production is used as the measure of net storage of radiant energy in the environment. This is accomplished mainly by photosynthesis in green plants whereby light energy is converted to chemical-bond energy and is stored in the plants through the synthesis of energy-rich sugar from energy-poor carbon dioxide. Carbon dioxide and water are the two compounds providing the key elements in organic matter: carbon, oxygen and hydrogen. Ninety-three percent of the dry weight of a tree has been estimated to derive initially from the carbon dioxide in air. Essentially, the entire seven percent balance of the plant's weight was derived initially from water (1). Only a trace amount was derived from elements in the soil.

Certain of these trace elements are essential, however, in the growth of all green plants. Many are components of enzymes which, in conjunction with chlorophyll, are used repeatedly by the plant and thus do not require continual replenishment. Minerals known to be required include nitrogen, phosphorus, potassium, sulfur, magnesium, calcium, and iron. Other elements are also needed but in much lesser amounts, including manganese, boron, chlorine, sodium, zinc, copper, and molybdenum. Elements such as vanadium, cobalt, silicon, and aluminum, may also be important but, if so, their role is uncertain.

Although there are many factors known to be of significance in governing the growth, distribution, and abundance of plants, factors of major importance in the growth of aquatic plants are nutrients, turbidity, salinity, and temperature. The following paragraphs provide an overview of the importance of these factors. For a more comprehensive discussion of the environmental factors that affect both plant and animal life in the Bay the reader is referred to Appendix 15: *Biota*.

NUTRIENTS

The growth of all aquatic plants depends on nutrients in the water, primarily nitrogen and phosphorus. Given a proper balance of other growth factors, such as sunlight, water temperature, presence of vital trace elements, and absence of toxic chemicals or other growth inhibitors, even a small amount of nutrient enrichment will trigger a bloom of algae or other aquatic weed. In certain instances, increased plant growth will occur predominantly among the phytoplankton. The waters become more turbid, discolored, and unpleasant in nature, and, in an advanced condition, have been characterized as being of a "pea soup" consistency.

While nutrient cycling mechanisms exist in nature the principal sources of man-related nutrient enrichment to the waters of Chesapeake Bay are (1) fertilizers from agricultural operations and animal feedlots, (2) effluents from wastewater treatment plants (3) runoff of stormwater from urban areas, (4) overflow and seepage from septic tanks, and in some cases, (5) wastes from pleasure craft. Almost every activity of man produces an effluent. Even the most routine personal actions can, in the aggregate, exert an appreciable effect on the aquatic chemical and biological environment. One man fertilizing his lawn will produce an undetectable increase in the nutrient loading of the water course. Thou-

sands of men innocently taking the same action may produce a blue-green algae bloom, dissolved oxygen depletion, and fish kills (4).

The largest contributor of nutrients to Chesapeake Bay is the Susquehanna River, which provides about 50 percent of the Bay's freshwater inflow, but more than 50 percent of the total nutrient input. Over the Susquehanna's 27,510 square mile drainage area and 453 mile length, the nutrient sources vary widely in type and location. An Environmental Protection Agency survey initiated in 1971 is seeking to identify these nutrient sources in the Susquehanna in order to provide a tool for possible control and management of this largest source of nutrients to Chesapeake Bay. Estimated nutrient contributions to the Bay are Listed in Table 14-1 for the major river sources (6).

TABLE 14-1

MAJOR NUTRIENT INPUTS TO CHESAPEAKE BAY

NUTRIENT LOADING* (lbs/day)

Tributary Watershed	Total Phosphorus as PO_4	Inorganic Phosphorus	Total Kjeldahl Nitrogen as N	Nitrite-Nitrate as N	Ammonia Nitrogen as N	Total Organic Carbon
Susquehanna River	33,000	20,000	93,000	153,000	29,000	513,000
Potomac River	23,000	9,900	35,000	57,000	6,000	267,000
James River	7,100	4,200	18,000	15,500	4,200	133,000
Rappahannock River	1,600	900	3,900	3,600	600	29,000
Pamunkey River	1,500	900	3,000	1,700	700	37,000
Mattaponi River	500	450	1,500	400	250	20,500
Chickahominy River	500	400	900	200	100	12,000

*Regression extrapolation of mean monthly flows, June 1969 to August 1970

Reference: (6)

In a particular drainage basin, the primary source of nutrient input may be from any of the sources mentioned above. Each individual drainage area or portion thereof has its own particular character and its own particular nutrient sources; thus, each drainage area must be dealt with on a source-by-source basis. In the Potomac River, the source of excessive nutrients is known to be primarily the waste effluents from the Washington Metropolitan Area. During periods of low flow in the river, 90 percent of the nitrogen and 96 percent of the phosphorus in the estuary are derived from these waste water discharges (5).

Although it is known that excesses of nutrients prompt increased photosynthetic activity in the water, there is no simple relationship between rate of plant growth and nutrient concentration. Using idealized conditions, nitrogen levels below 0.1 mg/l and phosphorus levels below 0.01 mg/l generally prevent algal growth (7). On the other hand, even with seemingly adequate nutrients, a triggering mechanism such as magnesium, certain trace elements, or some entirely unknown growth factor may be necessary to enduce an explosive bloom.

Nutrient loadings are highly related to river discharge as shown in Table 14-2 for the Susquehanna River at Conowingo, Maryland. The low flow of 22 October 1969 is compared with the high flow of 3 April 1970 along with the respective nutrient concentrations.

TABLE 14-2

NUTRIENT LOADS VS. STREAM FLOW, SUSQUEHANNA RIVER

Flow	Date	Nitrite-Nitrate (lbs/day) as N	Total Phosphorus (lbs/day) as PO_4
4,300 cfs	22 Oct 1969	15,000	3,200
264,000 cfs	3 Apr 1970	1,400,000	683,000

Reference: (6)

The relationship between river discharge and nutrient loadings especially nitrates and nitrites ($NO_2 + NO_3$) as N, is due to the increased land runoff that would be expected during high flow periods. Conversely, total phosphorus as PO_4 is more difficult to characterize since it tends to be adsorbed by particles and sediments in the water. During low flow periods, phosphorus is retained in bottom deposits in the stream channel. As a result, a substantial portion of the PO_4 is unavailable because of sedimentation. During high flow periods, scouring may occur in the waterway, thus releasing the nutrients retained in the sediment and transporting them downstream and ultimately into Chesapeake Bay (6).

Although the majority of nutrients are transported to the Bay during periods of high flow, more significance may be attributed to periods of low-flow. During low-flow periods, the nutrients are often allowed a high "residence time" in the subestuaries. This provides perfect conditions for algal blooms if other growth factors are favorable (6). For example, after the massive influx of nutrients accompanying Tropical Storm Agnes in 1972, a major nutrient input to the Rhode River was observed to enter this small subestuary from the Bay (8). The nutrients were rapidly lost to the bottom sediments until other parameters such as temperature and light triggered the intense algal blooms of the summer of 1972 (8).

TURBIDITY

Turbidity also has a significant impact on the ability of a body of water to sustain plant growth. Sediments from land runoff and shoreline and stream bed erosion cloud the water and reduce photosynthetic activity, especially during periods of high stream flow. In the presence of nutrients, which also increase markedly during periods of high stream flow, blooms of several species of green and blue-green algae may occur, contributing to the turbidity of the water, and further occluding light penetration. Under these conditions, rooted plants do not receive sufficient light to become successfully established.

In recent years, the importance of turbid waters as a limiting factor in the growth of both beneficial and problem aquatic plants has been demonstrated in Chesapeake Bay. The Bay's bottom of clay, silt, and combinations of muck or peat is easily roiled by excessive waves or currents in the unprotected shoals (9). The mantle of submerged vegetative cover which is normally present has been almost completely destroyed in the upper areas of Chesapeake Bay by the lack of clear water required for the growth of the plants (9).

In addition to the problems faced by fish and other aquatic life that are forced to live in the murky waters, and increased erosion problems caused by the loss of vegetative cover, several species of plants that serve as important sources of food for waterfowl have been lost over wide areas (9). Dominant native plants that have contributed to making the Chesapeake Bay one of the major waterfowl areas along the Atlantic Coast, and which have suffered a decline in recent years, include wildcelery and naiad in fresh waters, and redhead grass, sago pondweed, and widgeongrass in brackish waters. The situation has deteriorated to the point that a noted authority has recommended a moritorium on the control of such nuisance species as watermilfoil in order to reduce turbulent water movements and allow the reestablishment of native submerged vegetation (9).

SALINITY

Salinity is a measure of the dissolved salts content of the water. Salinities in the Bay range from about 30 parts per thousand (ppt) at the mouth of Chesapeake Bay to nearly 0 ppt at the head of the Bay and its tributaries. Average summer salinities in Chesapeake Bay are shown in Figure 14-2 (10).

Salinity is known to be one of the major environmental factors affecting the growth, distribution, and abundance of aquatic plants in Chesapeake Bay (5). This fact becomes quite evident during periods of high variability in freshwater inflow to the estuary. Periods of abnormally low streamflow result in increased saltwater intrusion into the Bay system and a subsequent reduction in the growth of aquatics having a low salinity tolerance. For example, extensive growths of watermilfoil and other submerged aquatics were reduced substantially during the droughts of 1933-34 (11).

Following a resurgence of growth during the 1940's and 1950's, the drought of 1964 through 1966 again reduced the numbers of aquatic plants, particularly watermilfoil (11). The reduction in such species as watermilfoil allowed redhead grass and to a limited extent sago pondweed and widgeongrass to reestablish themselves in some areas.

Large inflows of freshwater have the effect of reducing salinities in the Bay which in turn can affect those species of aquatic plants that flourish in more saline waters. The rainfall and subsequent flooding associated with Tropical Storm Agnes in 1972, seriously effected some species of aquatic plants. During a 10-day period, Susquehanna River flows averaged 15.5 times greater than normal and accounted for 64 percent of all freshwater inflow to the Bay (8). The massive volume of water translated the 5 ppt isohaline 30 nautical miles down the Bay. Widgeongrass, Eurasian watermilfoil, water celery, naiads, and macrophytic algae all decreased significantly as a result of lowered salinity and increased turbidity (8).

The salinity tolerances for some of the aquatic plants found in the Bay area are shown in Table 14-3. The values shown are upper levels of tolerance with many of the species capable of florishing in salinities lower than the limiting values shown. As noted on Table 14-3, widgeongrass and eelgrass are the most tolerant of high salinities and the northern species of pondweeds are the least tolerant (11).

TABLE 14-3

SALINITY TOLERANCE OF SUBMERGED AQUATIC PLANTS OF THE CHESAPEAKE BAY AREA

a. Under salinity of 1 ppt or 3% Sea Salinity (SS)

Potamogeton robbinsii	Fern pondweed
P. nodosus	Longleaf pondweed
P. amplifolius	Bigleaf pondweed
P. gramineous	Variable pondweed
Najas minor	Eurasian naiad
N. gracillima	Slender naiad
N. flexilis	Northern naiad
Heterantera dubia	Water-stargrass

b. Salinity 3 ppt or 9% SS

Nitella spp.	Nitella
Potomogeton pusillus	Slender pondweed
Najas guadalupensis	Southern Naiad

c. Salinity 3-5 ppt or 9-15% SS

Chara spp. (not all *Chara* spp.)	Muskgrasses
Vallisneria americana	Wildcelery

d. Salinity 12-13 ppt or 36-39% SS

Elodea canadensis	Elodea
Myriophyllum spicatum	Eurasian watermilfoil
Potamogeton crispus	Curly Pondweed
Ceratophyllum demersum	Coontail

e. Salinity 20-25 ppt or 60-75% SS

Potamogeton perfoliatus	Redhead grass
P. pectinatus	Sago Pondweed
Zannichellia palustris	Horned Pondweed

f. Salinity over 30 ppt or 100% SS and over

Ruppia maritima	Wigeongrass
Zostera marina	Eelgrass

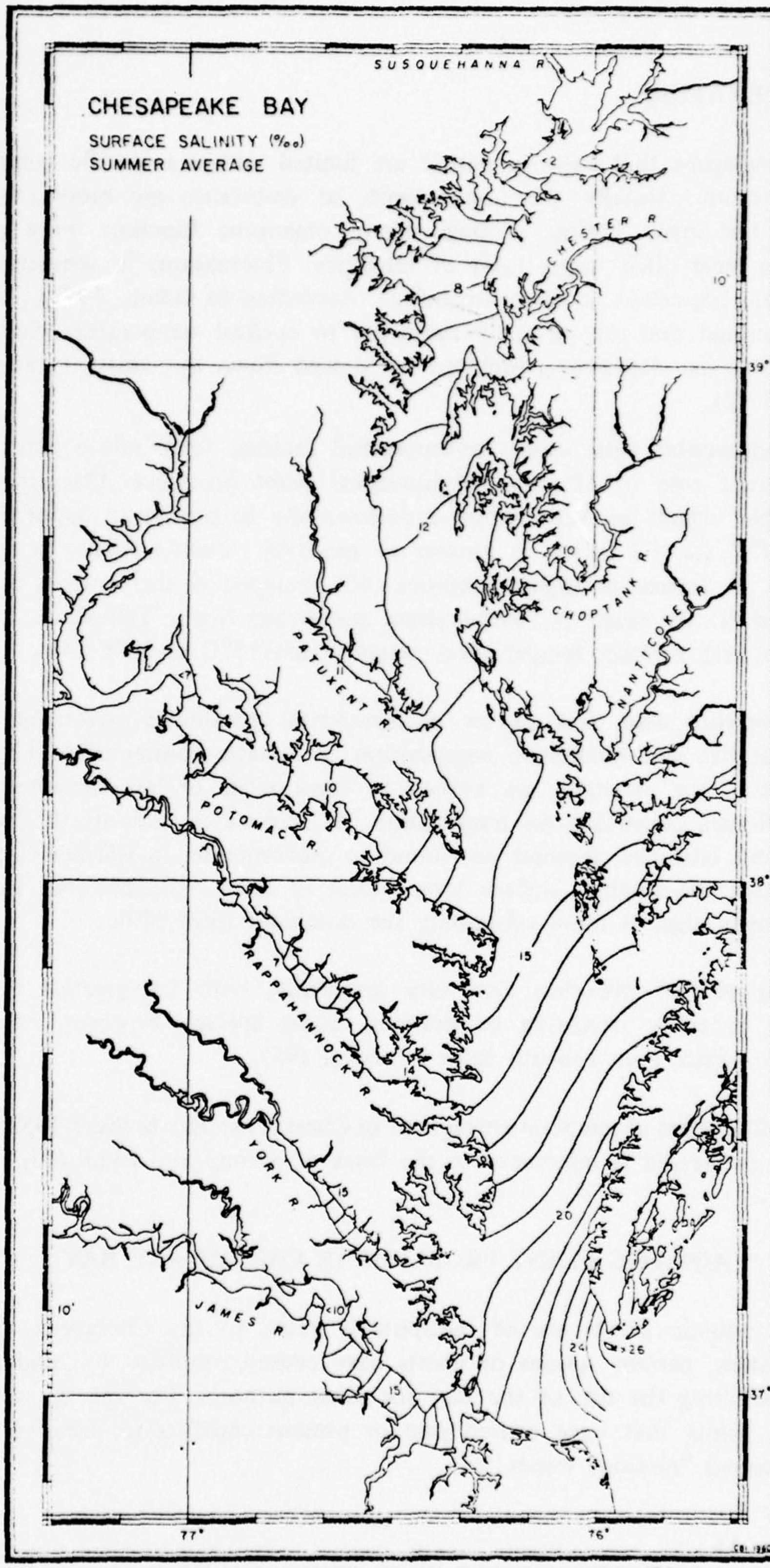


FIGURE 14-2: SUMMER AVERAGE SURFACE SALINITY (°/oo)

TEMPERATURE

All organisms that exist in nature are limited within a specific range of temperature. Usually the upper limits of endurance are more critical than the lower limits, although many organisms function more efficiently near their upper limit of tolerance. Fluctuations in temperature are also important to many organisms. According to Odum, 1971, plants and animal that are normally subjected to cyclical temperature changes "tend to be depressed, inhibited or slowed down by constant temperature" (2).

In conjunction with other environmental factors, temperature plays an important role in affecting physiological plant processes. Eelgrass, for example, which has been shown experimentally to survive an upper limit of 34°C for 12 hours, is known to generally tolerate higher temperatures in waters of higher salinities (45). Eelgrass is also known to be limited in its range by temperature, preferring North Temperate zone waters with summer temperatures ranging from 15°C to 20°C (45).

Temperature also acts as an environmental parameter governing the quantitative and qualitative composition of aquatic communities. Phytoplankton, for example, are known to form more or less characteristic assemblages depending on temperature. In cold-water lakes of the more northern latitudes, diatoms are found to predominate. In warmer climes, in which the summer surface temperature of lakes exceeds about 19°C, blue-green algae is more commonly the dominant form (49).

Populations of plankton also vary seasonally, with the greatest abundance generally occurring in summer. Some species, however, exhibit winter pulses, even beneath thick ice cover (45).

For an analysis of temperature regimes in Chesapeake Bay between 1952 and 1961, the reader is referenced to the work of Stroup and Lynn (10).

AQUATIC PLANT PROBLEMS IN CHESAPEAKE BAY

While aquatic plants are of indisputable value to the Chesapeake Bay ecosystem, certain species of plants have caused problems by hindering or restricting the use of the Bay for other purposes. For this appendix, those plants that have caused past or present conflicts in resource use are termed "noxious weeds."

On a world wide basis, noxious weed problems are of more concern in warmer latitudes than in the Chesapeake Bay Region. Central and South America, Africa, Asia, and the Southern United States all have more acute problems, with the state of Florida alone spending almost $15 million annually on weed control programs (12). While certain aquatic plants have caused problems in the Bay Region in the past, today only an occasional isolated report of a noxious weed problem can be found. The problem species are still present in the Bay waters, but only as mere fragments of previous volumes, and none in sufficient numbers to require comprehensive control measures.

It should be noted that in addition to the decline in problem plant populations, other species of submerged vegetation have suffered marked declines in the Bay Area during the last decade (9, 13, 14). Some of these are important waterfowl foods, others are important in the community structure of many organisms in the Bay ecosystem. In any case, one of the biggest problems in the upper fresh and brackish waters of the Bay, as characterized by one veteran Bay observer, is the *loss* of the usual vegetative cover in the shallow water (flocculent shoal) areas of the Bay (9).

The following sections provide both a detailed description of the species that could become troublesome in Chesapeake Bay and the types of problems caused by them.

AQUATIC PLANT PROBLEMS

Although aquatic plants are known to perform a basic function in the workings of the earth's ecosystem, they can also cause problems in waterways. Problems arise when plants occur in such a place or to such an extent that they restrict other beneficial water-related uses such as navigation, recreation, fish and wildlife, water quality, and public health. The impact on specific uses is discussed in the following subsections.

1) *Navigation.* Aquatic plants can grow sufficiently dense to block or impede boat traffic, damage propellers and engine cooling systems, and present a navigation hazard, particularly in the vicinity of bridges, docks, and piers. Boats used for both recreation and commercial purposes are affected, particularly by plants with dense underwater mats of stems, and laterals, such as alligator weed and water chestnut.

2) *Recreation*. Excessive growths of vegetation can affect water-based recreation in several ways. In addition to the hinderance presented to recreational boaters, water skiers, and sailors, weeds can restrict or even prevent access to recreational waters. Swimming may also be precluded or at least made less enjoyable in areas which would otherwise be well suited for this type of activity. Weed growths can also indirectly affect the recreation experience by providing a nursery ground for large swarms of mosquitoes.

3) *Fish and Wildlife*. Many species of fish and wildlife depend on the availability and abundence of certain plant species; however, excessive growths of plants can adversely affect fish and wildlife when (1) the decomposition of large volumes plants exhausts the dissolved oxygen in the water, (2) large expanses of plants occlude needed sunlight essential for basic food production, and (3) dense growths of plants render shallow water spawning areas and shellfish beds unusable as a result of increasing sedimentation. In regard to wildlife, drifting mats of weeds can destroy beds of submerged plants, defoliate floating-leaved aquatics and overwhelm or "crowd-out" plants which may be more desirable foods for waterfowl. Excessive weed growths may also hinder the harvesting of valuable commercial finfish and shellfish.

4) *Water Quality*. Dissolved oxygen, or DO, is a water quality parameter widely used to measure the suitability of a water body to support a healthy population of fish and other aquatic organisms. DO concentrations normally range from 5 to 15 ppm depending on water temperature and other variables, but waters enriched by nutrients from waste discharges, land runoff, or other sources may become depleted of DO where the enrichment has encouraged an excessive growth of aquatic plants. When the plants begin to die, bacterial decomposition depletes the DO and otherwise creates an unaesthetic condition.

The type of problem caused by the decay of vegetable matter remaining after an infestation or "bloom" will vary depending on the type of water body and the relative extent of the infestation. In waters subject to continual tidal action and mixing, such as the open waters of Chesapeake Bay, problems of plant decay do not generally grow to large proportions as plant growth is hampered in moving waters and there is a greater dilution of the available nutrients. In ponds and other small, shallow bodies of water such as slack waters and embayments the problem can be more serious because a relatively small amount of

organic material can deplete existing supplies of DO due to the relatively small volume of water present and the usually higher water temperatures. As less oxygen is retained in warm water and bacterial action is accelerated, the two factors together can make a more critical situation. Beneficial organisms may be removed by suffocation, and, if conditions deteriorate further, to the point of virtual elimination of DO in the water, anaerobic decay of the material will follow. Anaerobic conditions are characterized by odoriferous releases of hydrogen sulfide gas and an overall unaesthetic situation.

Another DO related problem is the reduction of atmospheric reaeration of the body of water due to physical coverage of the water surface by plants. The reaeration reduction and oxygen depletion lowers the natural capacity of the waters to assimilate organic pollution which in turn may create septic and odor conditions and thereby destroy the value of the waters.

5) *Public Health*. Aquatic weed infestations can engender conditions which are not in the best interests of the public health. A loose, uncompacted mat of aquatic vegetation provides favorable conditions for the proliferation of mosquitoes which are a recognized vector of diseases such as malaria and encephalitis.

Water supply systems, which are in part responsible for the maintenance of the public health, are also sometimes affected by infestations of aquatic plants. Matted growths can clog and obstruct flow at the intake of the waterworks, thus increasing the cost of waterworks operation and maintenance. As noted earlier, the decomposition of aquatic plants may also degrade the quality of the water and thus require treatment measures beyond those normally used.

6) *Other Problems*. Because of a reduction in aesthetic values, large growths of aquatic plants can lower the value of waterfront property and second or recreational home development particularly in areas where large amounts of dead plants are washed ashore. Large masses of certain types of vegetation decaying on the shore can also create another problem. Hydrogen sulfide gas released by rotting sea lettuce can be strong enough to blacken house paint, tarnish household metals, and in some instances even be injurious to health.

Drainage and flooding are other areas of concern with respect to aquatic plant growth. When a natural stream or drainage canal is seriously congested or completely blanketed by aquatic plant growths, the discharge capacity is greatly reduced. Small channels and shallow waterways become ineffective. Retarded runoff can increase the stage, extent, duration, and frequency of flooding.

Lastly, the indescriminate eradication of weeds through the use of chemical, mechanical, or biological means can, if not controlled properly, create more serious environmental problems than the weeds themselves. A more detailed discussion of control measures and their impacts is included in the next chapter.

NOXIOUS WEEDS

The plants which have caused the most widespread problems in Chesapeake Bay include Eurasian watermilfoil (Myriophyllum spicatum L.), water chestnut (Trapa natans L.), and sea lettuce (Ulva spp.). While, as noted above, these species are presently not a problem in the Bay Region, a detailed description and history of each is provided due to their potential for reemergence in the future.

EURASIAN WATERMILFOIL

Description

Eurasian watermilfoil is a submerged aquatic plant having an appearance as shown in Figure 14-3. The plant grows over a wide range of environmental conditions, flourishing in water depths of up to 8 feet and in waters from fresh to 15 ppt salinity (or about 45 percent sea salinity) (14). It roots easily in bottoms ranging from hard packed sand to muck, and under the right conditions grows rapidly to the water surface, sometimes forming a dense interwoven mat of material. Generally speaking, watermilfoil cannot withstand wave action or shoreline currents as well as other plants such as wildcelery, redhead grass, sago pondweed, and wigeongrass (9). In addition, the high turbidity associated with roiled waters has been shown to limit growth of milfoil. As a perennial, the plant dies off in late fall and growth is renewed from the roots in early spring.

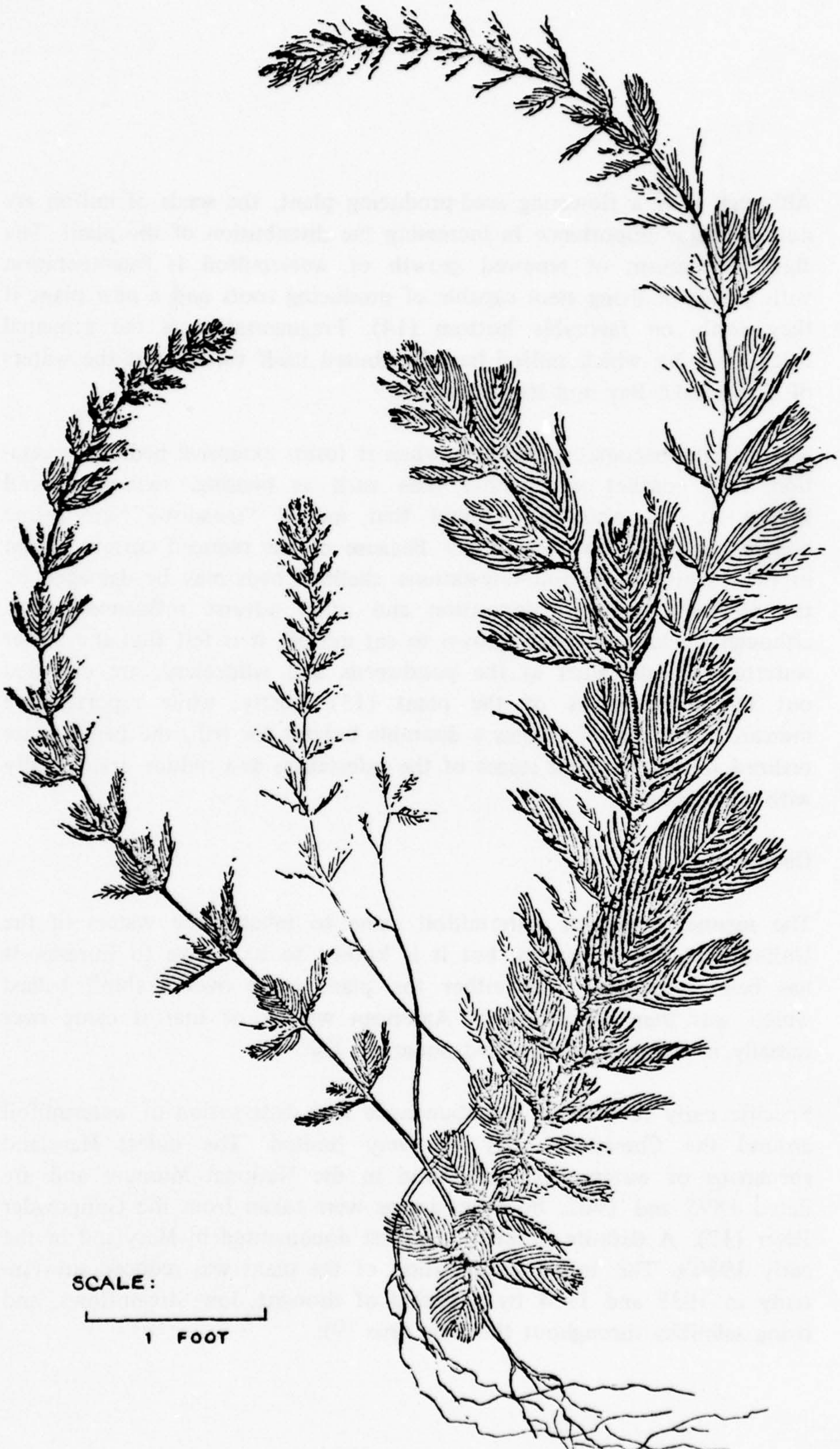


FIGURE 14-3: EURASIAN WATERMILFOIL (Myriophyllum spicatum)

Although it is a flowering seed-producing plant, the seeds of milfoil are not of major importance in increasing the distribution of the plant. The chief mechanism of renewed growth of watermilfoil is fragmentation with pieces of living stem capable of producing roots and a new plant if they settle on favorable bottom (14). Fragmentation is the principal mechanism by which milfoil had distributed itself throughout the waters of Chesapeake Bay and its tributaries.

Watermilfoil becomes a problem when it forms extensive beds of vegetation that conflict with other uses such as boating, swimming, and fishing. It has also been found that milfoil "meadows" are prime breeding grounds for mosquitoes. Because of the reduced current action in the vicinity of milfoil infestations, shellfish beds may be damaged by the resultant sediment deposition and other adverse influences. Also, although ducks have been known to eat milfoil, it is felt that the better waterfowl foods, such as the pondweeds and wildcelery, are crowded out by proliferations of the plant (15). Lastly, while reports have indicated that milfoil creates a desirable habitat for fish, the benefits are realized during the first stages of the infestation and reduce dramatically with time (16).

History

The manner in which watermilfoil came to inhabit the waters of the United States is uncertain, but it is known to be native to Eurasia. It has been postulated that either the plant came over a ship's ballast which was then discharged in American waters, or that it came over initially in supplies of imported aquarium fish.

Specific early records of the abundance and distribution of watermilfoil around the Chesapeake Bay are very limited. The oldest Maryland specimens of watermilfoil are found in the National Museum and are dated 1895 and 1902. Both specimens were taken from the Gunpowder River (17). A definite problem was first documented in Maryland in the early 1930's. This initial proliferation of the plant was reduced substantially in 1933 and 1934 by a period of drought, low streamflows, and rising salinities throughout the Bay Area (9).

Milfoil again surfaced as a problem in 1957. Evidence of the plant was recorded at many localities along the Potomac, including creeks and embayments in Charles, St. Marys, and Montgomery Counties, and in the Gunpowder and Middle Rivers in the Northern Bay. A survey made in 1960 estimated the extent of the milfoil infestation in Maryland at over 50,000 acres. By 1963, the milfoil growths approached 200,000 acres (17).

During this same period (1955-1965), infestations in Virginia waters were confined largely to the tributaries of the Potomac River. Unusually dense growths of the weed were reported on Lower Machodoc Creek in Westmoreland County in 1959 (15). Taskmakers Creek in Northumberland County was completely clogged with milfoil by the spring of 1963 (15). Small but noticeable colonies of milfoil were also reported in the Rappahannock River in the early 1960's. At the time, scientists differed over the possible impact on the 35,000 acres of shellfish beds in the Rappahannock.

By mid-summer of 1967, the mass of Eurasian watermilfoil inhabiting the waters around Chesapeake Bay had dwindled to an estimated one percent of its 1963 tonnage (17). In part, the reasons for the remarkable decline, as documented in the work of Harold J. Elser of the Maryland Department of Natural Resources, are Lake Venice disease and Northeast disease (17). Other theories on the decline of milfoil are related to the drought of the middle 1960's which caused salinity to increase in the Upper Bay and tributaries.

Because of their apparent importance regarding infestations of watermilfoil, the following information is provided on Lake Venice disease and Northeast disease.

a. *Lake Venice Disease*. This severe pathological condition was first discovered growing on watermilfoil in September 1962 in Lake Venice, a barrier-type pond of about 22 acres located in Anne Arundel County, Maryland (17). In 1961, 100 percent of the lake surface was covered with milfoil which at that time was flowering profusely. Periodic observations traced the fluctuations of the milfoil population and the "disease." By 1967, observations showed only a negligible amount of milfoil remaining in Lake Venice (18).

Although termed a "disease," it is not entirely certain that this phenomena accompanying the decline of milfoil is actually a disease. The chief characteristic is a very heavy overgrowth of diatoms, epiphytic algae, and various sessile protozoans. These organisms sometimes become so thick that, with the silt they collect, the leaflets become entirely obscured. The plant does not die immediately, but rather slowly wastes away and ceases to flower (17). In 1964, the Lake Venice "disease" was evidenced in almost all areas around the Bay containing milfoil (17).

b. *Northeast Disease*. The second "disease" was first noticed in the Northeast River, Maryland, in 1964. This condition is characterized by a stiffening of the stem and leaves. As the condition advances, the leaves fall off, leaving stiff bare stems which stand out of the water at low tide. These stems eventually disappear, probably by rotting away; however, the roots apparently are not affected because new growth can start in the area even before all the dead stems are gone. In late June 1964, the very extensive beds of milfoil in Seneca, Saltpeter, and Dundee Creeks in Baltimore County, Maryland, had all but disappeared, but by the first part of August, new growth had again reached the surface. In 1965, the Middle, Gunpowder, and Bird Rivers were added to the list of rivers containing Northeast disease. The "disease" apparently was not as severe as in 1965, and new growth reached the surface before all the old plants had disappeared (14). In 1966, Northeast disease was observed almost everywhere in the Maryland tidewater, and the remaining stands of milfoil were very thin–containing perhaps a quarter of their normal tonnage.

WATER CHESTNUT

Description

Like watermilfoil, the water chestnut (Trapa natans L.) is an import of Eurasian origin. The plant grows from seeds and produces as many as 10 to 15 rosettes or clumps of leaves which float on the surface of the water much like water lilies. The many rosettes of a single plant may form a cluster up to 10 feet in diameter (18). A single rosette of the waterchest is shown in Figure 14-4. In areas of intense growth, the rosettes may become so crowded that the leaves are pushed upright out of the water forming a continuous field of vegetation across the water. Boating, fishing, and other water related activities become difficult if not impossible. It has also been found that very few fish will frequent

these areas and that normal biological processes are terminated or severely reduced (14).

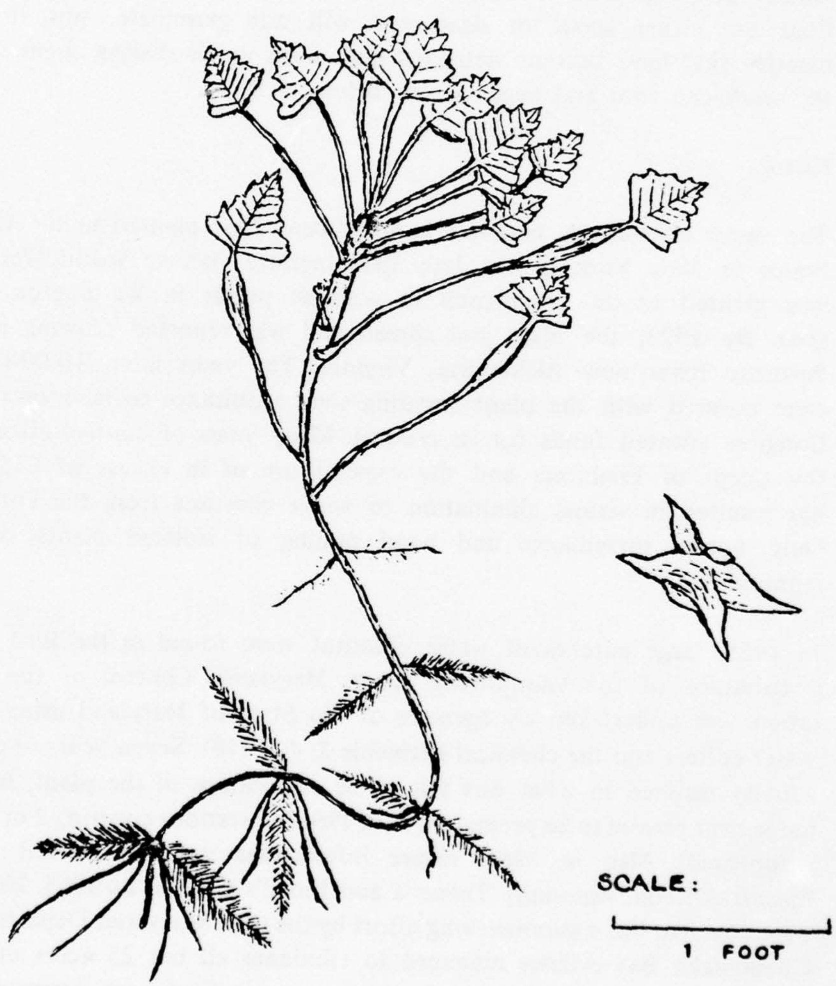


FIGURE 14-4: WATER CHESTNUT (Trapa natans)

The water chestnut is an annual and thus reproduces from seed only with each rosette capable of producing 15 to 20 seeds. Being an annual, it is possible to control the plant by selective cutting of the rosettes before they set their seeds. The seeds remain viable for as long as 12 years and each is about the size of a hickory nut and contains four large, very sharp spines which are a hazard to bare feet in beach areas.

The manner by which water chestnut distributes itself from one area to another is not fully understood, but the plant is known to tolerate no salinity and can grow in waters as deep as 15 feet. Generally, seeds that float are either spent or dead and will not germinate, but floating rosettes that have become detached may wash up in shallow areas where the seeds can root and begin a new colony (18).

History

The water chestnut is believed to have been first planted in the United States in New York in the late 19th century. Before World War I, it was planted as an ornamental in goldfish ponds in Washington, D.C. (14). By 1923, the plant had spread and was reported growing in the Potomac River new Alexandria, Virginia. Ten years later, 10,000 acres were covered with the plant, creating such a nuisance to navigation that Congress allotted funds for its control. Many years of control efforts by the Corps of Engineers and the expenditure of in excess of $550,000 has resulted in virtual elimination of water chestnut from the Potomac. Only yearly surveillance and hand pulling of isolated plants is now required.

In 1955, large patches of water chestnut were found in the Bird River, a tributary of the Gunpowder River, Maryland. Control of the infestation was undertaken by agencies of the State of Maryland using under water cutters and the chemical herbicide 2, 4-D (18). Seven years of control activity resulted in what was felt to be eradication of the plant, but this judgement proved to be premature as in 1964 infestations covering 2 or 3 acres reappeared. Also in 1964, severe infestations were discovered in the Sassafras River, especially Turner's and Lloyd's Creeks. By 1965, 200 acres were covered, but a summer-long effort by the then Maryland Department of Chesapeake Bay Affairs managed to eliminate all but 25 acres of them. Unusually high salinity concentrations were credited with destroying the remaining plants (14).

In the summer of 1966, a previously unreported raft of water chestnuts of about 40 acres was found in Day's Cove on the Gunpowder River. Again, mechanical control procedures by the State of Maryland, followed by annual survey and maintenance, were able to halt the invasion.

Water chestnut problems in Virginia waters, other than in embayments to the Potomac, are not known, or at least have not been reported to date, but the potential for growth of the plant in the fresh headwater areas of the Commonwealth should be cause for continued surveillance.

SEA LETTUCE

Description

Sea lettuce, including several closely related species of the genus *Ulva*, is a green alga with a world-wide distribution. The general appearance of the plant is shown in Figure 14-5. In the Chesapeake Bay, the species of particular concern is *Ulva latuca L.*, which grows in estuaries and salt marshes of low current velocity, and salinity as low as 12 ppt. The plant is equally at home in full ocean salinity. Typically, the plants grow at scattered 2 or 3 foot intervals to depths of about 20 feet. The plant is most abundant on shallow sand flats where it sometimes occurs in dense meadows covering several acres (19). Sea lettuce seems to be a good indicator of pollution as it often reaches its greatest abundance in the vicinity of sewage outfalls.

The problem associated with sea lettuce is not generally one of re stricted boating, swimming, or fishing (although some interference has been expressed by oyster tongers), but one of aesthetic degradation in the vicinity of the decomposing vegetation. The plant is usually attached to the bottom by means of a root-like appendage termed a "hold-fast"; but when detached, the plant bodies float with the wind and currents and often collect in small coves and embayments. Sometimes with the aid of heavy winds, the lettuce can accumulate to a depth of one foot. When washed on the beaches, it rots and produces various gasses, the worst of which is hydrogen sulfide. This noxious gas can discolor lead paint on waterfront houses, tarnish silverware, and, in sufficient concentrations, can create a health hazard (14). At the same time, the jet black decomposing material floats on the water surface or washes on the beach, forming a highly unaesthetic sludge of a greasy consistency. In

most cases, sea lettuce problems are only temporary as high water or storms carry the plant away thus eliminating the problem.

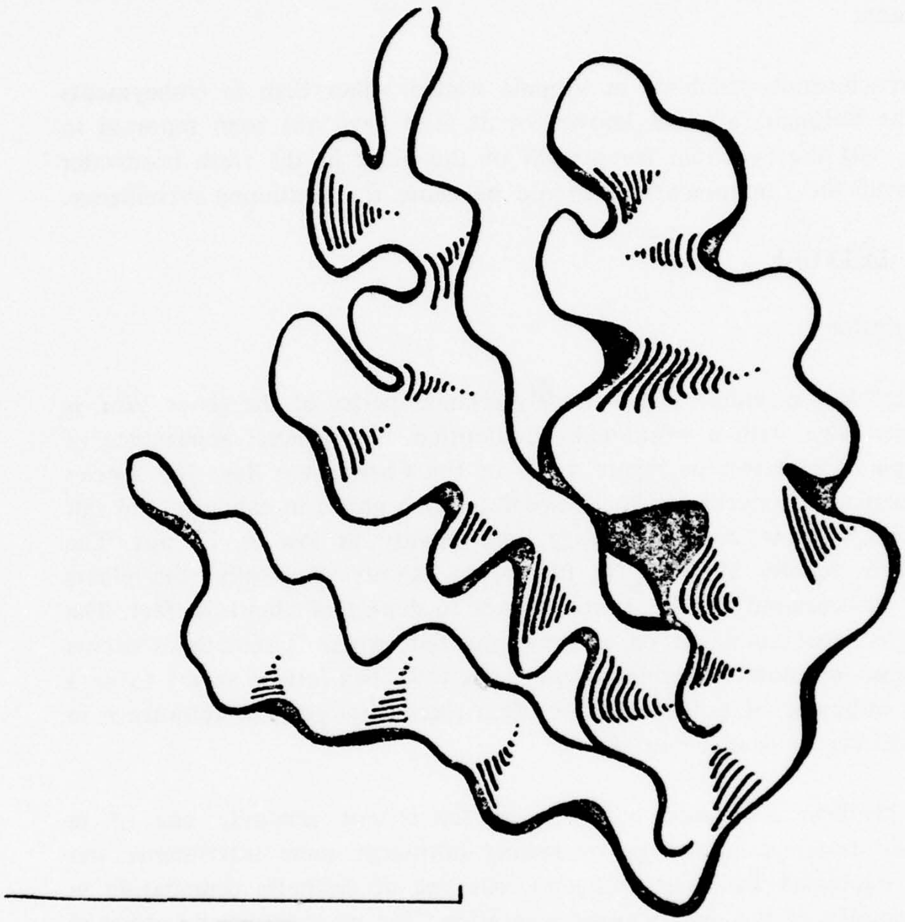


FIGURE 14-5: SEA LETTUCE (Ulva latuca)

History

Sea lettuce problems have been documented for many years in the Bay Area, Long Island Sound, and at many places along the back bays of the Atlantic Coast of New Jersey. The frequency of occurrence of

problems in Maryland increased during the early 1960's to a peak in 1965 when 34 problem areas were reported (19). Most of the problems were on the Western Shore and in the Potomac River and tributaries. The northernmost problem occurred at the mouth of Back River in Baltimore County.

The major problems related to sea lettuce in Virginia waters have occurred in the Norfolk area where local shoreline residents requested relief regularly during the 1960's. The myriad of waste discharges and nutrient sources in the Elizabeth River were blamed with promoting growth of the lettuce. Whether the expanded use of secondary treatment of municipal waste discharges in the Elizabeth River has caused a reduction in sea lettuce growth in recent years is unknown, but no problems were reported in 1974 or 1975 (20).

Most problems arising as a result of sea lettuce growth are only of a temporary nature. They typically remain only for two to six weeks, by which time tides or currents wash away the offensive flotsam. However, the problem is magnified by the fact that sea lettuce grows year-round. There are two known problem areas in Maryland which suffered continually with sea lettuce for three years (19). These long-term problems occurred at Owings Beach and Fairhaven in Anne Arundel County during the 1960's. Other infestations lasting as long as six months have been reported.

OTHERS

Other species of submerged aquatic plants have caused problems around the Bay Area in addition to the three species previously discussed.

a. Coontail, *Ceratophyllum demersum* L., is a largely freshwater plant that is found in the upper parts of the Bay. In freshwater lakes, this plant often grows in large floating clumps which can interfere with boating. Because wave action prevents formation of these mats, coontail has never posed a serious problem in tidal waters. It is also of considerable value as duck food.

b. Redhead grass, *Potomogeton perfoliatus* L., has been known to create somewhat of a nuisance, especially in Anne Arundel County, Maryland. It is quite tolerant of shoreline tidal and wave action and builds extensive meadows along open shores. As a valuable waterfowl food, redhead grass should be considered desirable in most cases. The

plant normally favors sandy bottoms to about 8 feet in depth and waters as high as 20 or 25 ppt salinity (14).

c. Elodea, *Elodea canadensis* Michx., is a widely distributed American species which grows in fresh and saline waters to about 12 ppt salinity. In the Chesapeake Bay Area, the plant generally occurs only locally, but is considered to have the potential for creation of great problems (14).

d. Brazilian waterweed, *Egeria densa* Planch., has been the object of an extensive weed control program in Walker Dam on the Chickahominy River, Virginia. An infestation of several submerged aquatics, primarily egeria, and including watermilfoil, had threatened use of the reservoir for recreational fishing and duck hunting, and for its intended use as water supply for the City of Newport News. A coordinated Federal and State control program, commencing in 1967, effectively cleared the impoundment through 1969. Subsequent reinfestation required renewed efforts in 1973 (21) (22).

e. Wild celery, *Vallisneria americana* Michx., is a highly rated duck food which grows in fresh water and saline water to perhaps 5 ppt. At one time, vast acreages of the plant were found in the Susquehanna Flats, where it is now essentially absent. Occasionally, the plant does grow thickly enough to impede boat traffic but its benefits definitely outweigh this minor inconvenience (14). In 1972, the wild celery almost completely disappeared from its former range and is only slowly beginning to a recovery (1974) (13).

f. Eelgrass, *Zostera marina* L., is a salt water plant which is often confused with wild celery since both species have long ribbon-like leaves. At one time, this plant was widely distributed along the Atlantic Coast from Hudson Bay to North Carolina and in Northern Europe. It has occurred in nuisance abundance in Long Island Sound where large masses of the plant have broken loose and accumulated on the beaches. In Chesapeake Bay, the plant is considered excellent cover for immature crabs, and an important waterfowl food, particularly for brant. It has not been a problem in the Bay Area to date. During the early 1930's, eelgrass was almost eliminated through much of its range (including Chesapeake Bay) by an, an yet, unidentified vector termed the "wasting disease" (3). A complete discussion of eelgrass and the important eelgrass community is included in the *Biota* appendix of the Chesapeake Bay Future Conditions Report (3).

g. Miscellaneous plants should also be mentioned which have the potential to become problems in the future. Various species of filamentous green algae (*Cladophora*) sometimes occur in large floating mats which are capable of stopping boat traffic. In addition, Widgeon grass (*Ruppia Maritima* L.), sago pondweed (*Potamogenton pectinatus* L.), bushy pondweed (*Najas flexilis*), and the various waterlillies and duck weeds are considered "potential troublemakers" (14). *Enteromorpha*, a species closely related to sea lettuce, but which grows in somewhat fresher waters, is extending its range and may also become a problem.

MANAGEMENT RESPONSIBILITIES

There are several Federal and State programs which provide varying degrees of assistance regarding aquatic plant problems. The services range from providing technical advice to the funding of control programs. The following paragraphs list those State and Federal agencies which have aquatic plant control programs and/or management responsibilities.

STATE OF MARYLAND

Within the State of Maryland, the Department of Natural Resources is the state agency most directly concerned with noxious weeds. Within the Department, the Capital Programs Administration, under the authority provided by the Waterways Improvement Fund of 1965, is responsible for the maintenance and/or clearing of navigable waters to include aquatic vegetation.

If chemicals are to be used to control the growth of aquatic plants, permits for the application of herbicides to any State waters are required from the Water Resources Administration, Industrial and Hazardous Wastes Section, Maryland Department of Natural Resources. All chemicals must be approved for use by the Environmental Protection Agency (EPA), and registered with the State chemist.

As noted earlier, there has been a decline in recent years of desirable species of plants. In 1976 a program was developed to improve submerged aquatic vegetation in the Bay and its tributaries. The program, administered by the Maryland Wildlife Administration, and the University of Maryland Center for Environmental and Estuarine Studies (CEES), in concert with a group of interested scientists, calls for three

years of observation, experimental plantings, and a controlled study of the factors affecting plant growth in order to provide guidance for further efforts to protect and enhance these resources. Experimental plantings by the Wildlife Administration were undertaken in the early summer of 1976 with the support of the U.S. Fish and Wildlife Service. The principal species under study include wild celery, redhead grass, sago pondweed, widgeongrass and eelgrass.

COMMONWEALTH OF VIRGINIA

The Virginia Commission of Game and Inland Fisheries has the authority to undertake control projects as they affect fish and wildlife resources. The authority for aquatic weed control is related to the agency's mandate to develop public fishing and boating and construct and maintain boat ramps. In addition, research-related weed control operations are sometimes undertaken by Virginia Institute of Marine Science. Virginia State Department of Health clearance is required for applications of herbicides to potable water supplies. The Department is charged with responsibility for the purity and fitness of any water supply for drinking and domestic use.

FEDERAL AGENCIES

Federal responsibility for the maintenance of navigable waters has been delegated to the U.S. Army Corps of Engineers. Section 302 of the River and Harbor Act of 1965 (PL 89-298), as amended, authorizes the Corps of Engineers to cooperate with other Federal and non-Federal agencies in comprehensive programs for control and eradication of obnoxious plants. Non-Federal interests must agree to hold and save the United States free from damages resulting from control operations and to finance 30 percent of the cost. The Federal Government may finance the research and planning cost of the program. Funds are allocated on a priority basis and there is a $5,000,000 annual limitation on Corps' expenditures for the total program. Funds appropriated are applied to three general categories: planning, control operations, and applied research. The legislation stipulates that the program be in the combined interest of navigation, flood control, drainage, agriculture, fish and wildlife conservation, public health, and related purposes. Furthermore, the law indicates the necessity for continuing research for development of the most effective and economic control measures as part of the program. This program for aquatic plant control on a National basis is

administered by the Chief of Engineers in cooperation with Federal and state agencies.

Under the authority for the construction and maintenance of channels in the Potomac River and tributaries at and below Washington, D.C., the Corps of Engineers has, since 1939, carried out a program for the elimination of water chestnuts from the Potomac River. These plants were at one time a serious menace to small boat navigation as well as to commercial and sport fishing, hunting, and public health. Prior to 30 June 1950, about 25,000 acres of dense growth were removed from the Potomac River and its tributaries with specially designed equipment. Since that date, work under the project has consisted of patrol during the growing season and the removal of scattered growth. Approximately $600,000 has been expended on this work since 1939.

Primary responsibility regarding the use of herbicides in water environments is held by the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA). The FDA, in their National Center for Toxicological Research, conducts research programs to study the biological effects of potentially hazardous substances found in man's environment. Tolerance limits are established for each chemical based on evaluation of biological and long-term low-level effects, the extrapolation of toxicological data from laboratory animals to man, and other criteria. New and updated regulations on tolerances are published from time to time in the Federal Register, Code of Federal Regulation, Title 40.

The development of guidelines for the registration of herbicides is the responsibility of the EPA's Office of Pesticide Programs. To satisfy the requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, the EPA is working toward development of "administratively adequate and scientifically defensible criteria for registering pesticides for use in aquatic sites"(23). An industry request for registration of a herbicide for aquatic use must include toxicology data for two species of mammals, and residue data for irrigated crops, meat, poultry, milk and eggs, fish and shellfish, and potable water (24). The Toxic Substances Control Act of 1976 also affects the use of chemicals in Bay waters. The Act authorizes EPA to regulate the manufacture, distribution, use, or disposal of any new chemical substance or the manufacture of any previously identified hazardous chemical substance.

The U.S. Public Health Service in its role as an overseer of safe drinking water has established allowable limits of herbicides in drinking water used by interstate carriers. The herbicides 2,4-D and 2,4,5-T are of particular concern as they have received rather widespread use.

Lastly, the U.S. Fish and Wildlife Service has an interest in aquatic plants and their control. The Service assists states in research and development of fishery resources, provides aid to state fish and wildlife agencies and evaluates the effects on fish and wildlife of Federal water resources projects.

CHAPTER III

MEANS TO SATISFY FUTURE NEEDS

Although present water resource utilization is not hindered by the presence of aquatic plant growth in the Chesapeake Bay Area, the potential exists for problems to develop in the future. All plants require that certain combinations of such growth factors as sunlight, salinity, temperature, and nutrients be correct before growth and reproduction will occur. It is not known whether it is an improper balance of these growth factors or some other reason such as disease which has caused the recent decline in aquatic vegetation; but, new growth can be expected with the return of favorable conditions. If a resurgence of aquatic plant growth creates conflicts with other uses of the Bay's resources, consideration will have to be given to control measures. This chapter provides an overview of the various measures that have been employed in the past and that have some potential for use in the Bay Region.

CONTROL MEASURES

Since the emergence of aquatic plant problems in America at the end of the nineteenth century, many methods have been devised to control problem growths. For example, early suggestions for control of water hyacinth in the Southeastern United States ranged from using salt, acid, and poisoning the water, to covering the water surface with kerosene or gasoline (25). Today, more sophicticated measures have been devised, researched, and put into practice, primarily with respect to plant problems in the southeastern United States. While the following overview of the advances in aquatic plant control relates mostly to the southeastern problem species, much of the information should prove valuable in evaluating similar problems in the Bay Region. For this discussion, the control measures are categorized as either chemical, mechanical, or biological.

CHEMICAL CONTROLS

One of the most direct and time effective means for the removal of nuisance growths of aquatic plants is through the use of chemicals. There are many compounds which can be used; however, many are

restricted or have only very limited applications due to their adverse side effects. Many herbicides are highly deleterious to aquatic organisms such as finfish and shellfish, and also may damage or eliminate desirable waterfowl food plants and other valuable vegetation. Another potential problem restricting the use of herbicides is the possible adverse effect on human beings who injest contaminated water or food. Voluminous regulations for residues of herbicides in agricultural products are published in Title 40 of the Code of Federal Regulation (CFR). Although much knowledge has been accumulated in recent years, much has yet to be done concerning the accumulation and concentration of herbicides and pesticides in the food chain.

Despite obvious drawbacks, the efficiency of chemicals in aquatic plant control has usually exceeded that of other alternatives. For example, mechanical cutters require a greater amount of time to control a given infestation and are limited to unobstructed areas, whereas chemical application by boat-mounted sprayers or from an aircraft enables treatment of a large area in a much shorter time. Usually, mechanical removal also causes fragmentation of the plants which, if not properly collected, are then free to drift with the wind and currents to initiate growth in new areas.

In areas in which chemical control of aquatic plants is clearly an advantage over other methods, and in which adverse impacts are not anticipated at the particular doseage, chemical herbicides may be used. Each of several chemicals commonly used for plant control are discussed in the following sections as to their applicability, limitations, and typical dosage.

Copper Sulfate. This compound is widely used for the control of algae with typical application rates varying from 0.05 to 2.3 ppmw in the pentahydrate form. Copper sulfate is toxic to fish, and except in hard water, should not be used at rates above 1.0 ppm (26).

2,4-D. Various derivatives of 2,4-D (2,4-dichlorophenoxyacetic acid) are applicable for use in control of submersed aquatic vegetation. One of the most commonly used derivatives has been the butoxyethanol ester (2,4–D BE) which has been used in the Chesapeake Bay area for control of Eurasian watermilfoil. Joint investigations by the U.S. Fish and Wildlife Service, the Maryland Department of Game and Inland Fish, the Chesapeake Biological Laboratory of the University of Mary-

land, and the Virginia Institute of Marine Science determined that 2,4-D BE, impregnated in clay particles and applied at rates of 20 to 30 pounds acid equivalent was effective for control of milfoil in tidal waters (27). The active ingredients are released slowly, allowing the time needed for the chemical to effect adequate control. The effective period for application is limited to the last 10 days in May and the first few days of June in tidal waters of the Chesapeake Bay. In lakes and ponds, 2,4-D can be used in the liquid form since tidal dispersal is not a problem as it is in the Bay proper.

Environmental effects of the use of 2,4-D in aquatic habitats have been quite heavily researched and observed, most notably in association with plant control programs in the reservoir projects of the Tennessee Valley Authority; and in Currituck Sound, North Carolina, and Chesapeake Bay (29-33). The toxicity of 2,4-D depends heavily on the formulating components—the ester derivatives, as a group, being most toxic (26). In laboratory assays, some toxicity to fish occurs near the maximum recommended treatment rates. Under field conditions, however, toxicity at maximum recommended rates has seldom if ever been observed (26). Clams and oysters have been found to acquire greater residue than fish and crabs (32). Regarding human consumption, Federal standards limit 2,4-D concentrations in public water supplies to 0.02 mg/1.

Field observations following the 1968 application of 2,4-D in Currituck Sound, North Carolina, showed no adverse effects to the benthic organisms in the area (glass shrimp, damselfy nymphs, scuds, and blue crabs) (34). In addition, applications at a rate of 20 pounds of acid equivalent per acre were found to control watermilfoil and subsequently release growth of native waterfowl food plants, such as widgeongrass, sago pondweed, and redhead grass (31).

Diquat. This chemical is often used where circumstances make it undesirable or unsafe to use 2,4-D. Diquat is injected into the water or sprayed on the water surface, being least effective in turbulent waters or in water containing appreciable quantities of suspended solids which adsorb the chemical making it ineffective. Diquat has been found to be non-toxic to wildlife, fish, and other aquatic animals when used at the recommended rates of 0.25 to 1.0 ppmw (26,35). For spot treatments in lakes and reservoirs, these application rates are frequently doubled to assure adequate weed control (26). The persistence of Diquat in the

environment is short with concentrations usually reduced to traces 3 to 4 days following treatment.

Diquat was used in equal parts with potassium endothall for control of *Egeria densa* in Walker Dam, Chickhominy River, Virginia, in 1967. Application to 200 surface areas at a rate of 1.5 gallons per acre unexpectedly resulted in freeing nearly the entire 1,100 acre reservoir of egeria after 30 days (36). It had been expected that only the treated 200 acres would be cleared of weeds.

Endothall. The various derivatives of endothall are active on a broad spectrum of submersed aquatic plants. The inorganic salts are usually used at 1.0 to 5.0 ppmw. Rates of 4.0 and 5.0 ppmw are used for spot or marginal treatments. Fish are not harmed at these concentrations and may be used for food three days after treatment (26). Because of their short persistence in water, swimming is permitted after 24 hours and other water uses may be resumed 7 days after treatment. The alkylamine salts of endothall are more toxic to plants and are also much more toxic to fish–0.3 ppmw may cause fish mortality (26).

Silvex. The potassium salt of silvex is applied as a liquid or sometimes in a granular or pelleted form. It is considered to be more phytotoxic to some aquatic plants than 2,4-D and is somewhat more persistent in the environment (26). Since it is of greater cost and of limited advantage over 2,4-D, silvex is not commonly used. When used, the recommended treatment rates are 1.5 to 2.0 ppmw or about 5 pounds per acre-foot of water. Other observations concerning 2,4-D also apply to silvex (26).

Others. Many other chemicals are applicable for use in water environments but are either highly toxic or persistent in the environment or are for use in special applications only. Fenac, for example, is used in situations in which water can be drawn down and the application made to the exposed bottom in weed infested areas. Dichlobenil, another chemical herbicide, can be used on exposed bottom or over the water surface, and, although it is not toxic to fish except at application rates 30 to 60 times the recommended rate, it is persistent in confined water and is not to be used in water used for domestic, irrigation, or livestock purposes (26).

Other herbicides, such as acrolein and aromatic solvent, are used in select areas such as irrigation ditches. They are both very toxic to fish. Grasses and grass-like plant species, including cattails and bulrushes, respond well to applications of dalapon.

In the extensive testing of chemicals in the initial effort against water hyacinths in the early 20th century, sodium arsenite was found to be the most effective control. The fact that this compound was later banned by law due to its toxicity to other forms of life, including man, points up a major concern: the hazards to flora and fauna accompanying use of poisons in the environment are often largely unknown or obscure. Due to these environmental concerns, all herbicides used in aquatic plant control operations require both Federal and State registration or "clearance" labels. These labels prescribe recommended uses, dosages, and use limitations. As an example, the registration labels proposed for 2,4-D BE are included as Figures 14-6, 7, and 8 (37).

MECHANICAL CONTROL EQUIPMENT

Mechanical aquatic weed control involves the use of various types of equipment to cut, uproot, collect, mash, and otherwise destroy the plants. A 50-foot steel ribbon with saw teeth on both edges and a wooden handle at each end has been used but because it requires great amounts of manual labor, it is not popular. Various V-shaped blades have been used to slice plants off at their base when dragged along the bottom. More advanced cutting machines which are either self-propelled or skiff mounted are also available. Another machine built for aquatic plant control is a jet spray which strips the bottom and uproots undesirable plant growth. This is of special advantage on swimming beaches where complete removal of the plant and its root system is required. Most of these devices require subsequent collection of the plant remains in order to prevent increased distribution and regrowth from the plant fragments.

2,4-D Granular Aquatic Weed Killer

Active Ingredients	29.0%

Butoxyethanol ester of 2,4-dichlorophenoxyacetic acid

Inert Ingredients	71.0%

Contains 20.0% 2,4-dichlorophenoxyacetic acid equivalent

CAUTION

Keep out of the Reach
of Children

To be applied by federal, state or local public agency personnel, trained in aquatic weed control, or by licensed commercial applicators under contract to the above agencies. For use in ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, rivers and streams that are quiescent or slow moving.

FIGURE 14-6: FRONT PANEL OF PROPOSED REGISTRATION LABEL FOR USE OF 2,4-D IN AQUATIC SITES

Directions for Use

For susceptible weeds – Apply 100 lb of this product per acre of water surface to control water milfoil, water shield, and water lily.

For more resistant weeds – Apply 150-300 lb of this product per acre of water surface to control coontail, elodea, waterweed, naiad, pondweed, water chestnut, water star grass, and yellow water lily.

When to apply – Early spring application when weeds are growing vigorously is best. In most instances, one early season treatment provides seasonal control and frequently can provide control up to 18 months, depending on the source of weed reinfestation.

If treatment is delayed until weeds form a dense mat of growth, a second treatment 4-6 weeks later may be needed to provide complete control for the remainder of the season. The final treatment must be applied before mid-August so that complete decomposition will occur before winter ice forms.

In treating tidal water embayments, apply granules immediately after the end of low-tide and work from the inlet or mouth of the embayment toward the innermost shore. Apply before flowering of weeds.

How to apply – For large, open-water areas, fertilizer spreaders or cyclone seeders can be adapted for use on boats or specially adapted spreaders on helicopters may be used. For small waterfront properties, granules can be broadcast by hand from a boat, raft, or dock.

Uniform distribution is very important. Square out areas to be treated. For large-scale applications, use guide poles at each end of the lake or pond.

FIGURE 14-7: LEFT PANEL OF PROPOSED REGISTRATION LABEL

Notice to Applicators

State and Local Coordination – Before application under any project program, coordination and approval of local and state authorities may be required, either by letter of agreement or issuance of special permits for such use.

Fish Toxicity – Oxygen Ratio – Fish breathe oxygen in the water and a water-oxygen ratio must be maintained. Decaying weeds use up oxygen. To avoid fish kill from decaying plant material do not treat more than one half the lake or pond at one time. For large bodies of weed infested waters leave buffer strips of at least 100 feet wide and delay treatment of these strips for 4-5 weeks or until the dead vegetation has decomposed.

Irrigation – Delay the use of treated waters for irrigation for three weeks after treatment unless an approved assay shows that the water does not contain more than .1 ppm 2,4-D acid. Do not treat irrigation ditches in areas where water will be used to overhead (sprinkler) irrigate susceptible crops especially grapes, tomatoes and cotton.

Potable Water – Delay the use of treated water for domestic purposes for a period of 3 weeks or until such time as an approved assay shows that the water contains no more than .1 ppm 2,4-D acid.

CAUTION
Avoid inhaling dust.

Avoid contact with skin,
eyes, or clothing.

Avoid drift of dust or granules to susceptible plants as this product may injure cotton, beans, peas, grapes, ornamentals, etc. Do not store near fertilizers, seeds, insecticides, or fungicides.

FIGURE 14-8: RIGHT PANEL OF PROPOSED REGISTRATION LABEL

Mechanical methods of control have been in use for some time. Perhaps the first plant control program of any type used a crusher which pulverized the plants and left the remains to sink and rot in the water. Implemented in 1900 in Louisiana, the crusher boat was found incapable of coping with the rapid rate of spread of the plants it was used to destroy.

Today, significant use is made of mechanical weed control by the U.S. Army Engineer District, New Orleans (38). Two types of craft are used. The "heavy-duty, roll-crusher, destroyer" was first built in 1937 and continues in effective use today. The vegetation is cut, fed on a conveyor, crushed at 40,000 psi pressure, and fed back into the water. The machine, known as the *Kenny*, is effective in destroying the principal regrowth factors in water hyacinth (the rhizome) and alligator weed (the node). A more recently developed machine is the "saw-boat destroyer," which cuts and mutilates 10,000 square yards per hour under normal conditions. Nine years of experience with the saw boat in the New Orleans District indicates that it can operate at $8 per acre cleared which is considerably less than other mechanical methods (38). Both the machines have depth of water and maneuverability limitations.

In the Chesapeake Bay, mechanical harvesters were used briefly by the State of Maryland in the mid-1960's, primarily for the control of water chestnuts in the Upper Bay. In open water areas where growth was concentrated, a mechanical harvester mounted on a barge was used. Various schemes were employed to dispose of the collected material to assure that regrowth from dislodged rosettes did not occur (39). Use of an apple picker on a 10-foot pole was found to be the most effective devise for collection of water chestnuts in scattered locations.

Mechanical control was used by the Corps of Engineers in the Potomac River in the 1950's. Underwater cutters were used to control 10,000 acres of water chestnut by severing the rosettes (containing the seeds) from the stem. After 10 years and expenditures of about $180,000, the program was put on an annual survey-type maintenance status, involving hand pulling of individual plants (40). In 1975, approximately 200 plants were pulled, but in most years the number is less than 100.

Newer types of equipment that have been investigated by the Corps for possible field operations include spray equipment, wood chippers, devices for transporting personnel and equipment over difficult terrain, amphibi-

ous tractors, and even a machine which floats on its own cushion of air at speeds up to 60 miles per hour (25). Since chemical control measures should be limited because of adverse effects on the environment, more emphasis is presently beeing given to control by mechanical methods. The disposal of large volumes of harvested plant materials is a large problem which requires additional study.

BIOLOGICAL CONTROLS

Biological control of noxious aquatic plants is perhaps the most ideal from a cost and permanence point of view. This type of control is self-perpetuating at virtually no cost other than that needed to initiate the process. Biological control can be in the form of a pathogen or insect or animal predator species. Most desirable would be an organism or disease that is host specific (i.e., attacks only noxious species) and self-perpetuating over time.

The most active use of biological control measures in the United States has been in the southeastern states. One of the most notable successes has been the introduction of the South American flea beetle, *Agasicles hydrophila*, for control of alligator weed. The program implemented by the Corps of Engineers in cooperation with the U.S. Department of Agriculture, Entomology Research Division, has shown the beetle to be host specific, but somewhat restricted in its latitudinal range (25). Since its introduction, the *Agasicles* beetle has become established from Georgia to Texas and has become an important factor in the control of alligator weed.

Herbivorous fish have also shown considerable promise as biological control agents. If the particular species is acceptable as a sport fish and can also be utilized for food, the acceptability is much enhanced. The white amur is perhaps the most promising of all fish that have been tested (26,48) and may have some applicability in Chesapeake Bay. The amur is tolerant of a wide range of temperatures and will consume many species of plants. Although the amur has been found to be very effective for weed control in lakes in Arkansas, apprehension remains concerning the ecological effects of introduction, since little investigation of the amur's effects on other species has been undertaken. Other animals which have potential as biological controls include snails, crayfish, thrips, moths, grasshoppers, aphids, and the manatee (an aquatic mammal).

Plant diseases or phytopathogens, are another category of biological control. Plant pathogens are numerous, highly diverse, easily disseminated, self-maintaining, host specific, capable of limiting the population without eliminating the species, and are nonpathogenic to animals (41). At the same time, the literature pool for pathogens of aquatic plants is almost nonexistent and identification and determination of host-range for each disease organism is an immense task. Also, experimental introduction of plant pathogens must be done with extreme care so as not to endanger desirable plants (4).

Diseases of aquatic plants are not well known, but some have been identified. Most of the research has been targeted toward pest species of the southeastern United States: water hyacinth, alligator weed, hydrilla, and watermilfoil (42). Since most of the worst aquatic plant pests are of foreign origin, searches for pathogenic and other biological controls have been generally oriented overseas (41). Disease causing agents identified include bacteria, fungi, mycoplasma, nematodes, and viruses.

Of further interest is the fact that many diseases are in some manner associated with various insect related injuries to the plant which further complicates the use of diseases to control water weeds. Efforts are under way to explore insect-disease complexes (42).

Biological controls are not known to have been intentionally used in the Chesapeake Bay for the control of noxious weeds. However, as discussed earlier, several diseases have been observed in the Bay Region and may have contributed to the decimation of much submerged aquatic plant life around the Bay area (17). Infestation of milfoil totaling between 100 and 200 thousand acres in 1963 were reduced to an estimated one percent of their previous tonnage by 1967. At that time, healthy milfoil was not found anywhere in Maryland (17). Bacterial cultures isolated from these diseased milfoil plants were of 14 varieties from five taxa (42), but attempts in Florida to transmit these diseases to healthy milfoil were unsuccessful.

OTHER METHODS

Other methods for the control of noxious weeds have been devised including the physical modification of the environment. One approach involves occluding sunlight from the plant, eventually causing death. The procedure can involve injecting inky fluids into the water or the use of black plastic sheeting stretched and fastened over the weed bed. These

methods have been attempted, but found effective only in limited situations such as boat docking facilities or marinas and in areas of limited wave and current activity.

Another physical method which has been found most effective in the control of watermilfoil in lakes managed by the Tennessee Valley Authority is dewatering by drawing down the lake to a level below the infestation (43). The dewatered reservoir banks must be well-drained and left exposed between 4 and 6 weeks to assure complete drying of the milfoil roots and stems.

An elaborate electro-mechanical, barge-floated laser beam apparatus has been devised and tested by the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi, in coordination with several other agencies and institutions. In 1970 and 1971, studies were conducted using several configurations of the laser beam to burn and kill the portions of aquatic plants extending above the water. Continued experimentation is ongoing, and certain questions remain unresolved, but it has been found that control of plants is feasible using this method (44).

MANAGEMENT MEASURES

Although the control measures discussed in the preceding paragraphs are the most direct solutions to site specific aquatic plant problems, consideration should also be given to measures that address the sources of the problems on a Bay-wide scale. Noxious weed problems are not divorced from other water resources and man's use and development of the lands surrounding the Bay. An extensive, long-term management program for noxious plants should include a comprehensive view of related water and land activities, particularly as they relate to nutrient sources. Nutrients especially from urban and agricultural runoff and municipal waste discharges are one of the primary keys to aquatic plant problems in the Bay. As mechanical or chemical measures may be only a temporary solution, nutrient control through the management of land related activities may be a more logical approach to certain aquatic plant problems. In this regard, it is expected that the implementation of the water quality management plans being prepared by the states under the authority of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) will have a significant effect on the growth of aquatic plants in the Bay. Lastly, since many of the more troublesome species of plants were introduced in this country either deliberately or accidentally, measures to control the importation of possible problem species could aid in the prevention of future problems.

CHAPTER IV

REQUIRED FUTURE STUDIES

As noted in the preceding chapters, there are presently no serious noxious weed problems in the Bay Region; however, the potential exists in the future for conflicts between aquatic plant growths and other resource uses. In order to formulate a comprehensive aquatic plant control program that can adequately address the future problems and alternative solutions, additional studies and research are required.

Additional research and investigation into methods of aquatic plant control are needed to supplement efforts that have been made to date. The development of new and refined mechanical, chemical, and biological methods will enable more efficient and cost effective control of noxious weeds while at the same time minimizing impacts on the environment.

Envrionmental concerns are of major importance in control operations particularly with regard to fish and wildlife resources. Additional studies are warranted regarding the flow of plant nutrients and energy in the aquatic ecosystem and the effect of chemical controls on producer organisms, and subsequently, on organisms in higher trophic levels such as fish (28).

Many of the above environmental questions will be answered as progress is made towards registration of additional aquatic herbicides. Registration of herbicides for use in aquatic sites requires extensive experimentation as to toxicity and persistence in the environment. What is needed is a balance sheet approach to understanding the full spectrum of events associated with the uses of each herbicide. As functions of herbicides are more clearly understood, the registration process can be made more sound and a quantitative evaluation prescribed for each component of the registration formula (47).

Dr. E. O. Gangstad, plant control specialist with the U.S. Army, Office Chief of Engineers, has summarized the current needs status as regards use of aquatic herbicides (47):

> "Only after we have developed and published such information (discussed above), can we expect intelligent use by consumers and greater acceptability by those concerned about the effects of chemicals on environmental values. Everyone agrees that scientific assessments should replace emotional concerns and reactionary responses. As our knowledge of the behavior and fate of pesticides grows, we should be able to develop a relative environmental exposure index for each pesticide. Such an index would require assessment of toxicity, dosage, total use, and persistence, among other factors."

In areas of biological plant control methods, much additional research work remains to be done. The number of insects, snails, fish or pathogenic organisms which could conceivably act as man's ally in the control of pestiferous aquatic plants is very large and many have never been isolated nor identified. Although biocontrol agents possess great promise in the area of noxious weeds, they must be researched carefully and thoroughly and released only after it has been shown that they present no hazard to the land or water environment. Finally, the high potential and desirability of pathogens as an aquatic weed management tool warrants much greater research emphasis in this area.

Regarding mechanical control measures, additional effort is required to identify more efficient and cost effective techniques and machinery. Related to mechanical control is the problem of disposal of the harvested material. Research into uses for the weeds, such as silage for livestock and/or fertilizer for crops, would enhance mechanical measures as a means of control.

Since aquatic plant growth is highly related to man's use of the Bay's resources, long term solutions to noxious weed problems require a comprehensive management approach particularly as it relates to those activities affecting water quality. For example, the siting of a major treatment plant or determining the impact of reduced freshwater inflows requires studies to determine how the proposed actions may affect the growth of both beneficial and noxious aquatic plants.

With regard to evaluating the impact of proposed structural and management actions on aquatic plants, the Chesapeake Bay Hydraulic Model should prove useful in providing some of the physical data required to make an evaluation. For example, since the normal habitat of water chestnuts is restricted to freshwater or tidal waters of no salinity, the

model could be used to determine changes in salinity patterns and thus changes in suitable water chestnut habitat that may result from a proposed action. The model can also be used to determine the dispersion and eventual fate of effluents that would enhance or stimulate the growth of aquatic plants. Lastly, the model should be helpful in defining the dispersion and eventual fate of chemical control agents that are applied to eliminate growths of noxious weeds. A more detailed discussion of the capabilities of the hydraulic model and examples of the type of test that can be conducted may be found in Appendix 16, *Hydraulic Model Testing.*

REFERENCES

1. Keeton, William T., *Biological Science*, W.W. Norton and Co., N.Y., 1967.

2. Odum, E. P., *Fundamentals of Ecology*, W. B. Saunders Co., Philadelphia, 1971.

3. *Chesapeake Bay Study, Existing Conditions Report*, Appendix VII: "Biota," U.S. Department of the Army, Baltimore District, Corps of Engineers, 1973.

4. *Chesapeake Bay Study, Future Conditions Report*, Appendix 12: "Fish and Wildlife," Draft, 1976.

5. *Existing Conditions Report*, Appendix XI: "Water Quality," 1973.

6. *Chesapeake Bay Nutrient Input Study*, EPA Region III, Annapolis Field Office, T. R. 47, 1972.

7. McGauhey, P. H., *Engineering Management of Water Quality*, McGraw- Hill Co., New York, 1968.

8. Chesapeake Research Consortium, *Impact of Tropical Storm Agnes on Chesapeake Bay*, 1975.

9. Steenis, J. H., *Status of Eurasian Water Milfoil and Associated Submersed Species in the Chesapeake Bay Area, 1969*, Patuxent Wildlife Research Center, 1970.

10. Stroup, E. D., and Lynn, R. J., *Atlas of Salinity and Temperature Distributions in Chesapeake Bay 1952-1961*, Chesapeake Bay Institute, 1963.

11. Steenis, J. H., and Gangstad, E. O., *Salinity Observations on Eurasian Watermilfoil and Associated Submerged Species in the Chesapeake Bay Area*, Contribution of the Wetland Ecology Section, Patuxent Wildlife Research Center, 1970.

12. Freeman, T. E., and Zettler, F. W., "Biological Control of Aquatic Weeds with Plant Pathogens," *Aquatic Weed Control with Plant Pathogens*, WES, Technical Report 8, 1974.

13. Kerwin, J. A., Munro, R. E., and Peterson, W. W. A., *Distribution and Abundance of Aquatic Vegetation in the Upper Chesapeake Bay, 1971-1974*, U.S. Fish and Wildlife Service, Laurel, Maryland, 1975.

14. Elser, H. J., *Status of Aquatic Weed Problems in Tidewater Maryland, Spring, 1967*, Maryland Department of Chesapeake Bay Affairs (MDCBA), 1967.

15. Bailey, R. S., and Haven, D. S., "Milfoil," *Virginia Wildlife*, date unknown.

16. *Reconnaissance Report, Aquatic Plant Control Program*, North Atlantic Division, Corps of Engineers, 1967.

17. Elser, H. J., *Observations on the Decline of Watermilfoil and Other Aquatic Plants, Maryland, 1962-1967*, MDCBA, 1967.

18. Elser, H. J., *Control of Water Chestnut by Machine in Maryland*, 1966.

19. Elser, H. J., *Formation of Sea Lettuce Problems in Maryland, 1965*, MDCBA, 1965.

20. Wootton, F., Chief, Planning Branch, Corps of Engineers, Norfolk District, Personal Correspondence, February 1976.

21. Berry, C. R., Schreck, C. B., and Corning, R. V., *Control of Egeria in a Virginia Water Supply Reservoir*, Virginia Polytechnic Institute (VPI), date unknown.

22. *Final Environmental Statement, Walker Dam Impoundment, Aquatic Plant Control Project*, Norfolk District, U.S. Army Corps of Engineers, and Virginia Commission of Game and Inland Fisheries, 1972.

23. Burkhalter, T. D., "Criteria for Herbicide Evaluation," presentation at *Research Planning Conference*, October 1973, WES, 1974.

24. Hummell, R. J., and Cummings, J. C., "Registration of Herbicides for Aquatic Use," *Research Planning Conference*, WES, 1974.

25. Raynes, J. R., *Research and Control of Obnoxious Aquatic Plants*, presentation at ASCE Meeting, January, 1972.

26. Gangstad, E. O., et. al., "Registration of Aquatic Herbicides," *Research Planning Conference*, 1973, Appendix D, WES, 1974.

27. Stennis, J. H., and Stotts, V. D., *Tidal Dispersal of Herbicides to Control Eurasian Watermilfoil in the Chesapeake Bay*, presentation at Southern Weed Conference, Dallas, Texas, January 1975.

28. Walker, C. R., *Herbicide Chemicals and Their Effect on the Aquatic Environment*, Contribution of the Branch of Pest Control Research, Bureau of Sport Fisheries and Wildlife, USDI, 1971.

29. Duke, T., "Effects of 2,4-D Formulations on Estuarine Organisms," *Butoxyethanol Ester of 2,4-D for Control of Eurasian Water Milfoil*, Technical Report 12, WES, 1976.

30. Gangstad, E. O., et. al., "Butoxyethanol Ester of 2,4-D for Control of Eurasian Water Milfoil," *Technical Report 12*, WES, 1976.

31. Hall, A. B., et. al., "Changes in Structure and Metabolism in a Eurasian Water Milfoil Community Following 2,4-D Treatment," *Technical Report 12*, WES, 1976.

32. Rawls, C. K., "The Accumulation and Loss of Field-applied Butoxyethanol ester of 2,4-D in Eastern Oysters (*Crassostrea virginica*) and Soft-shelled Clams (*Mya arenaria*)" *Hyacinth Control Journal*, Vol 9, 1971.

33. Fish, F., "EIS for the control of Eurasian Water Milfoil, Currituck Sound and Kitty Hawk Bay, North Carolina," *Technical Report 12*, WES, 1976.

34. Smith, G. E., and Isom, B. G., "Investigation of Effects of Large Scale Applications of 2,4-D on Aquatic Fauna and Water Quality," *Pesticides Monitoring Journal*, Vol. 1, 1967.

35. Haven, D. S., *Levels of the Herbicide Diquat in Two Estuarine Molluscs and In the Water and Mud*, Contribution No. 308, VIMS, 1969.

36. Corning, R. V., and Prosser, N. W., "Egeria Control in a Potable Water Supply Reservoir," *Hyacinth Control Journal*, Vol. 7, 1968.

37. US Army Engineer Waterways Experiment Station, Aquatic Plant Control Program, *Technical Report 12*, Appendix B, 1976.

38. Thompson, W. E., "Mechanical Equipment Used for Aquatic Plant Control in Louisiana," *Proceedings, Research Planning Conference, 1972*, WES, 1972.

39. Elser, Harold J., *Control of Water Chestnut By Machine in Maryland, 1964-1965*, Maryland Department of Chesapeake Bay Affairs, 1966.

40. US Army Corps of Engineers, North Atlantic Division, *Reconnaissance Report, Aquatic Plant Control Program*, New York, 1967.

41. Freeman, T. E., et. al., "Utilization of Phytopathogens as Biocontrols for Aquatic Weeds," *Proceedings, Research Planning Conference, 1973*, WES, 1974.

42. Gangstad, E. O., *Aquatic Weed Control with Plant Pathogens*, Contribution to Technical Report 8, WES, 1974.

43. Smith, Gordon E., et. al., "Eurasian Water Milfoil in the Tennessee Valley," Contribution to *Technical Report 12*, WES, 1976.

44. US Army Engineer Waterways Experiment Station, *Effect of CO_2 Laser on Water Hyacinth Growth*, Technical Report 11, 1975.

45. US Army Corps of Engineers, Chesapeake Bay Study, *Future Conditions Report*, Appendix 15: Biota, 1976.

46. US Army Engineer District, Norfolk, and Virginia Comm. of Game and Inland Fisheries, *Final Environmental Statement, Walker Dam Impoundment, Aquatic Plant Control Project*, 1972.

47. Gangstad, E. O., Preface to *Technical Report 12*, Aquatic Plant Control Program, WES, 1976.

48. Michewicz, J. E., Sutton, D. L., and Blackburn, R. D., "The White Amur for Aquatic Weed Control," *Weed Science*, Vol. 20, 1972.

49. Reid, George K., and Wood, Richard D., *Ecology of Inland Waters and Estuaries*, Van Nostrand Co., New York, 1976.

50. Seliger, Howard, Technical Report, 1976.